Report to

PUBLIC UTILITIES COMMISSION
CITY AND COUNTY OF
SAN FRANCISCO

Review of

WATER QUALITY
MANAGEMENT PROGRAM
SAN FRANCISCO
WATER DEPARTMENT

MAY 1984

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May 17, 1984

Mr. Rudolf Nothenberg
General Manager
Public Utilities Commission
City and County of San Francisco
287 City Hall
San Francisco, California 94102

Dear Mr. Nothenberg:

We are pleased to submit the following report describing our review of the Water Quality Management Program for the San Francisco Water Department. Our review covers an evaluation of current water quality management practices and recommendations for future changes and considerations in light of pending revisions in drinking water regulations.

During the study, we have had full cooperation from members of your staff and the Water Department. We appreciate your effort in particular in providing information to us so that a comprehensive and objective evaluation could be accomplished.

It has been our pleasure to serve you on this most important project.

Respectfully submitted,

Franklin L. Burton

Franklin L. Burton
Vice President

Olivia L. Chen

Olivia L. Chen
Project Manager

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SAN FRANCISCO WATER QUALITY
MANAGEMENT PROGRAM REVIEW

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EXECUTIVE SUMMARY

In accordance with the authorization dated October 6, 1983, Metcalf & Eddy, Inc. has completed its review of the Water Quality Management of the San Francisco Water Department.

The work to be performed consists of an assessment of the following areas:

1. Raw Water Quality Control. Security, sanitation, and quality controls at all Water Department local terminal reservoirs located in Alameda, San Mateo, and Santa Clara counties.

2. Operation of Filtration Plants. Adherence to all applicable standards for operations, maintenance of records, technological training, and plant performance at San Andreas and Sunol filtration plants.

3. Quality Control in Distribution System. Effectiveness of (a) disinfection programs: adherence to applicable standards covering bacteriological matter, THM formation, other volatile organic matter, contaminants, asbestos, etc.; (b) cross-connection control program; and (c) corrosion control program.

4. Operation of Laboratory. Effectiveness of all testing programs and adherence to required standards, maintenance of records, and technological training.

5. Alternatives to Chlorination. Desirability of conversion to sodium hypochlorite and chloramine.

A summary of historical water quality data for water that is being delivered to the distribution system is presented in Table 2-1. The treated water meets in every respect the current legal water quality standards of the USEPA and the State of California, Department of Health Services.

The USEPA currently has an Advance Notice of Proposed Rules Making, published in October 1983, that announces its intention to propose National Revised Primary Drinking Water Regulations

for organic, inorganic, microbial, and radionuclide contaminants in drinking water. Should such changes be made, the State of California would be mandated to adopt the new regulations. Our assessment of the water quality management, therefore, is performed with the objectives of addressing the City's ability to meet potentially more stringent requirements and to streamline and better the current operation.

ADDITIONAL TREATMENT REQUIREMENTS

To meet future more stringent requirements on turbidity, Giardia lambia, and/or asbestos, it would be necessary to filter all of the Hetch Hetchy supply. Since the USEPA proposed regulations are still in promulgation, enforcement dates cannot be projected.

The Water Department has evaluated the needs for the total treatment of its water supply. The addition of the 40-mgd Crystal Springs treatment plant and the expansion of the 40-mgd San Andreas plant to 80 mgd have been planned. Design and construction of these facilities will proceed when the bond election for its funding is approved by the voters of San Francisco.

The filtration of the Hetch Hetchy water has been planned to be located near the Sunol plant. We recommend the Water Department proceed with pilot plant studies on the Hetch Hetchy water to evaluate alternative treatment processes and select the most cost-effective process for future implementation.

A pilot study should be conducted for a year to cover seasonal water quality changes. The cost of the Phase 1 pilot study will be approximately $500,000. This estimate includes operation labor and materials for pilot plant construction. Laboratory support is assumed to be provided by the Millbrae laboratory and is not included. The Phase 2 demonstration project will vary depending on the process selected.

RAW WATER QUALITY CONTROL

Hetch Hetchy Watershed

- In the Yosemite Park area, surveillance provided by the Park Rangers of the watershed area satisfies the City's current needs.

- Since there will be no development permitted on park land, potential for future deterioration of water quality in the Hetch Hetchy due to manmade reasons appears to be minimal.

- The eutrophication process is a natural phenomenom which takes place in all bodies of water. Nutrient materials are washed into the lakes and streams and increase the growth of algae. With increased algae blooms, some water quality deterioration will occur in future years.

- There is some evidence of Giardia cysts in the watershed. However, the potential risk is not well defined and is currently being studied by DOHS.

Storage Reservoirs

- There is no recreation activity or development allowed on City-owned watershed land. The potential of reservoir water quality degradation due to man's activities is minimal.

- The eutrophication process in terminal reservoirs will take place sooner than that of the Hetch Hetchy system due to the different size of the reservoirs.

- Watershed keepers, whose primary responsibility is security and maintenance of grounds, assume the responsibility of water quality surveillance. More formal training and direction are needed in the area of water quality management for watershed keepers.

- Cattle grazing activities on the leased property near Calaveras and San Antonio will not create a significant threat to public health because all waters in these watersheds are impounded in reservoirs and receive complete treatment at Sunol prior to entering the transmission system.

- The only area of water quality concern is at Moccasin Reservoir:
  - The lack of copper sulfate application during summer months results in algae problems.
  - State Department of Health Services' concern with Giardia may require filtration of water that is being supplied to the communities of Early Intake and Moccasin.

The watershed management currently being practiced by the San Francisco Water Department is satisfactory for the protection of the sources of raw water.

With respect to the occurrence of algal problems at Moccasin in the summer months, we expect improvements when the water supply pipeline to the downstream fish hatchery is completed. Timely addition of copper sulfate to the reservoir water should control the algal growth at the reservoir.

To obtain better control of water quality at Moccasin, we recommend that the water quality at Moccasin Reservoir be closely monitored during the summer months and grab samples be obtained on a weekly basis for analysis of plankton counts.

Pending the outcome of the Giardia Study conducted by the DOHS, the City may be required to provide filtration for the communities of Early Intake and Moccasin. The cost of installing package filtration systems is approximately $50,000 each including chemical feed systems and housing.

OPERATION OF TREATMENT FACILITIES

Operation of the treatment facilities is satisfactory. The conditions at Rock River lime station, Tesla Portal chlorine station, Sunol treatment plant, San Andreas treatment plant, and the City chlorine stations are to be complimented. The conditions at Casey Quarry and fluoride station are marginal and are presently being improved.

To streamline operations and formalize procedures, we recommend the following.

Lime Station (Rock River)

The lime station operation at Rock River is satisfactory to provide the necessary treatment of Hetch Hetchy water for corrosion control. To provide proper protection of pipes and the concrete lining of the City's vast water transmission system, we recommend that the lime feedrate be determined on a weekly or biweekly basis. The stationary engineer can run simple laboratory tests and set the feedrate to bring about a positive corrosion index. The expenditure on training will be about 8 hours; labor requirement on conductivity tests will be 1 to 2 hours biweekly. The investment for an analytical apparatus would be less than $1,000. To effectively stabilize the aggressiveness of the water, the feasibility of adding electrolytes should also be investigated.

There is only one stationary engineer assigned to the post with the stationary engineer at Tesla Portal as relief personnel. We recommend that one additional person be assigned and trained to operate the station as backup. The backup operator can be supported from the Hetch Hetchy Division at Moccasin, or can be assigned from the Sunol filtration plant.

Chlorine Station (Tesla Portal)

The Tesla Portal facility is satisfactory in providing disinfection for the Hetch Hetchy supply. The only area needed to be addressed is the determination of the chlorine feedrate to maintain desired chlorine residual at the Alameda East Portal.

Recognizing that the Tesla Portal facility provides for disinfection of 80% of the City's supply, it is crucial that we recommend correlation of the variables (flow, turbidity, travel time, chlorine demand, chlorine residual, etc.).

The objective of these evaluations is to establish the methodology for determining necessary chlorine feedrates and to maintain more consistent and desirable chlorine residual levels in the treated water.

Presently, relief for the stationary engineer is provided by the stationary engineer at Rock River. We recommend a stationary engineer from the Sunol plant be assigned as backup.

Water Filtration Plants

Both Sunol and San Andreas plants are maintained in excellent condition and operate satisfactorily with finished water meeting all latest drinking water regulations on a continuous basis. There is a formal training program to provide the staff with the latest water treatment information and to enhance operation efficiency. To provide full shift supervision, we recommend the addition of a senior stationary engineer and a stationary engineer for each plant.

The areas that could use improvement at these plants are the ability to provide building and structure maintenance and major preventive maintenance for the mechanical equipment. We recommend this be accomplished by:

1. Continue the use of Suburban Division maintenance personnel. A crew of one painter and three machinists should be assigned to work at the treatment plants continuously to perform preventive and corrective maintenance. The same crew should be used to maintain continuity of machinery services.

or

2. Add a painter for building maintenance and three machinists to perform the necessary duties for both treatment plants.

One other option is to contract outside services through UEB. This arrangement will increase administration costs at UEB. Considering the need is on a continuous basis, it would be more economical to the City to retain this work within the Water Department.

Other Treatment

Chlorination. In addition to the Tesla Portal and the treatment plants, chlorination of the Suburban system is provided at the following locations:

- Sunol Aqueduct
- Peninsula Aqueduct (two locations)
- Casey Quarry (supplemental and emergency)

All of these chlorination stations operate continually except for the Casey Quarry installation where security and maintenance are marginal and left room for improvement during our visits. The Water Department has taken corrective actions to improve this facility. We recommend the continuation of scheduled improvements and that security be checked on a regular basis.

Fluoridation. Fluoridation is applied at the San Andreas water filtration plant and at three other fluoride stations. The conditions at the major fluoridation station near the north portal of the Crystal Springs Bypass Tunnel left much to be desired during our visit. Leaks were evident throughout the piping system. The four fiberglass reinforced plastic storage tanks are not presently installed in containments. The Water Department has included in the 1984-85 budget installation of containments for these storage tanks. A leak detection probe is being installed on the sump. We recommend the continuation of scheduled improvements.

Reservoir Turbidity Control. There are three alum treatment installations used to control runoff turbidity from streams entering into Crystal Springs and San Andreas reservoirs. Alum is fed at a continuous rate during winter storms to coagulate and coalesce the particulate matter in the runoff. Alum used in the 1982-1983 water year exceeded one million pounds. The dissolved aluminum concentration at Crystal Springs Reservoir is 0.09 mg/L as compared to 0.04 mg/L at San Andreas and 0.03 at Pilarcitos. This higher aluminum content may be caused by this practice.

The Water Department has considered discontinuing this practice because Crystal Springs Reservoir water is not being delivered directly to users. The concern for turbidity control has been in the case the reservoir is used to supply the distribution system directly under emergency conditions. Continuing application of alum in these emergency circumstances may improve water quality to be delivered.

We recommend a more in-depth evaluation be conducted, correlating previous water quality data, particularly turbidity readings and particle counts at the reservoir outlet, with alum applications and the dissolved aluminum concentrations in the reservoir. Additional turbidity readings should be taken during the 1984-85 storm season without the alum application. The objective will be to evaluate the water quality impact of the alum application and decide the continuation of such practice.

DISTRIBUTION SYSTEM WATER QUALITY CONTROL

Chlorination Stations

The San Francisco Water Department has developed and maintained an extensive chlorination system within the City distribution system for the control of microbiological contaminants. The system provides an adequate level of disinfection, thereby

meeting the principal objective of safeguarding the public's health. The bacteriological readings are within current regulations. Adequate chlorine residual is maintained throughout the distribution system. All of the chlorination stations are being operated and maintained in satisfactory condition.

The chlorine handling, transportation, and safety precautions are adequate. Each station maintains minimum storage of chlorine gas to reduce the hazard potential to neighbors. However, this practice increases the frequency of chlorine handling and truck traffic. We recommend more storage be provided to minimize handling and consequently reduce the potential for chlorine accidents.

We also recommend the City incorporate in the future replacement program the vacuum feed system for the chlorinators. The City can also choose to install pressure reducing devices on the gas feedlines to accomplish the same purpose. The cost of a new vacuum system will be $2,300 each and the installation of the pressure reducing device will be approximately $1,300 each.

Cross-Connection Control Program

The current cross-connection control program is a citywide effort involving also the Department of Public Works and the Department of Public Health. The Water Department is responsible for the largest share and is currently taking the lead role.

The Water Department is currently monitoring all industrial users, hospitals, and high rise buildings. Schools and Caltrans facilities are planned for inspections in the near future. Inspections will also include the San Francisco Port Authority.

The Department of Public Works is responsible for checking cross-connections on all public buildings and possibly all Park and Recreation Department facilities.

The Department of Public Health is responsible for restaurants and swimming pools.

An ordinance on cross-connection which establishes a water quality control committee in the City and County has been introduced to the Board of Supervisors. The ordinance places the Water Department in a lead role on the committee.

The Water Department's cross-connection program, staffing level, procedures, recordkeeping, and equipment are satisfactory. To facilitate communication among the three agencies prior to the adoption of the cross-connection ordinance, we recommend an informal task force represented by all three departments be established in the interim to provide the necessary information exchange and to enhance the effectiveness of the program.

Corrosion Control Program

Corrosion control for facilities of a large water agency such as the San Francisco Water Department consists of two elements: internal corrosion control and external corrosion control.

Internal corrosion control is the protection of the interior surfaces of water conveying structures, pump stations, and pipelines. External corrosion control involves the protection of buried piping systems and structures, and the protection of above ground facilities.

Internal Corrosion Control. The Water Department's main internal corrosion control effort is the lime plant operation at Rock River.

Depending on the amount of blending with waters from Alameda County and the Peninsula reservoirs, the corrosion indexes vary within the conveyance and distribution system with no

identifiable pattern. This is caused by the low buffering capacity of the Hetch Hetchy water which presents difficulty in lime stabilization. The Water Department is planning to undertake a study to evaluate the water chemistry and the corrosion behavior of the water supply.

The Water Quality Manager is responsible for the Rock River lime station and the Assistant Water Quality Manager is responsible for the on-going corrosion study. Two staff members from the Millbrae laboratory are involved on an as-needed basis. The Water Department is adding an associate water quality engineer position to undertake a more comprehensive study program, including the addition of more monitoring stations and the evaluation of using other corrosion inhibitive chemicals such as zinc orthophosphate.

With the addition of one associate water quality engineer to the staff, the City's internal corrosion control program can be implemented satisfactorily provided study results are used to improve the current practice. We also recommend increasing the monitoring stations to ten locations and extending the monitoring period to 3 years.

Also, we recommend the following inclusions in the future evaluations:

1. Evaluate the use of alternative corrosion inhibiting chemicals, their effectiveness, and water quality implications.

2. Evaluate the changes in lime feedrates as related to asbestos counts in the water system.

3. Analyze heavy metal content at selected locations in the City's distribution system to obtain a general picture of metal pickup.

External Corrosion. Currently, approximately $100,000 per year is budgeted for external corrosion control studies. Projects are

initiated by the division directly involved with the particular facility to be studied. A project manager from the Utilities Engineering Bureau budgets for the project and programs for the completion of the work. Presently, there is no formal corrosion control program designed for the San Francisco water system.

Many studies have been conducted on the external corrosion conditions along the Hetchy-Hetchy system and main pipelines in the Suburban system. In the City distribution system, corrosion conditions are being observed during repair work and replacements. Recognizing the size of the City's water system and the amount of investment to be protected, we recommend that a comprehensive corrosion control program be implemented. The program should consist of three elements:

- Evaluation
- Implementation of corrective action
- Maintenance of corrosion control facilities

Evaluation. In addition to the projects that are being completed, a complete evaluation of all water system facilities is recommended to assess the total magnitude of the problem:

1. Existing conditions of the facilities and conditions of damage. Emphasis should be on the City's distribution system where minimum work has been performed.
2. Causes of corrosion problems.
3. Areas in which corrosion control improvements are needed.
4. Establishment of priorities, schedules, and budget for the improvement program.

Implementation. The improvement program should be budgeted in accordance with the schedule. Corrosion control systems should be designed, tested, and installed.

Maintenance. Once the corrosion control systems are installed, calibrated, and operated, the system must be tested and maintained for optimum service.

Budget. A comprehensive corrosion control program is a costly undertaking and should be an on-going program to protect the City's investment and to prolong the life of the facilities. This is of particular importance because many parts of the City's system have exceeded their expected design lives. Any extension to the life of the facilities represents savings to the City. The cost impact can be recognized from the estimated replacement cost of City pipelines. For 1984, the replacement cost is estimated to be $375,718,000. The achievement of 1% improvement will translate to a $3,000,000 savings for 1 year.

It is estimated that a comprehensive evaluation program will require approximately 3 years. The cost of the first phase evaluation including the development of a comprehensive improvement program is about $300,000 to $400,000 total for 3 years. The improvement program should indicate the improvement elements, annual budget requirements for the first 5 years, and also estimate the funding requirements and other necessary improvements in 5-year increments for a program span of 20 years.

The program should be updated every 5 years so that more updated cost figures can be developed and incorporated into the budgetory process.

Staffing. Presently, all corrosion control projects are being implemented through UEB. We recommend that the position of one full-time corrosion engineer at the level of associate engineer be created to coordinate and implement the corrosion control effort. This corrosion engineer position can be located in the UEB or in the Water Department, reporting to the Water Quality Manager or the Assistant Water Quality Manager, similar to the cross-connection control program. One part-time technician

should be assigned to the corrosion engineer to routinely take readings and maintain the corrosion control facilties.

OPERATION OF LABORATORY

The Millbrae water quality laboratory's primary duty is to perform routine analyses to satisfy the regular reporting needs to the State Department of Health Services.

The laboratory also conducts sampling and analyses of the raw water reservoirs and of water along the Hetch Hetchy and Suburban system to monitor the water quality changes. In addition, the laboratory analyzes water samples related to customer complaints.

Recognizing the changing regulatory requirements and the increased concerns of consumers with respect to public health issues, we recommend the role of the laboratory be expanded to include:

1. Provide the proper checks-and-balances of the water system operation on every day operation of the system, performing the primary function of quality control.

2. Provide support directly to the Hetch Hetchy, Suburban, and Water Quality divisions in evaluating current operational practices, conducting research projects, and recommending future improvements in an effort to better the services that are being delivered.

Recommendations made in this section are aimed at the accomplishment of these objectives.

Organization and Staffing. We recommend the addition of a laboratory director to the current staff, with the following responsibilities:

- Administer the laboratory personnel
- Prepare annual budgets, equipment, and personnel requisitions
- Establish formal quality control/quality assurance program
- Determine sampling program locations, frequencies, and analyses to be performed
- Coordinate with other division managers and identify research subjects
- Direct study projects
- Interpret laboratory results
- Direct statistical and trend analyses
- Follow development of federal drinking water regulations and identify areas of need
- Perform staff training

Organizationally, the laboratory can be separated from the Water Quality Division. The Laboratory Director reports directly to the General Manager or the Assistant General Manager.

An alternative will be to have the water treatment superintendent in charge of all treatment facilities and operations.

The Water Treatment Superintendent and the Laboratory Director will be reporting to the Water Quality Manager independently to provide the checks-and-balance necessary in an organization for production and quality control.

This organization modification suggests four separate functions under the Water Quality Manager:

- Water treatment - production
- Laboratory - quality control and research
- Cross-connection prevention
- Corrosion control program

Sample Locations and Schedules. To accommodate the additional workload generated from the new duties, it is necessary to reevaluate the existing sampling program. Our examination of the existing sampling frequency and analyses that are being performed suggests that the current sampling program be closely evaluated; the potential for reducing the sampling frequencies of various constituents is discussed in Chapter 6.

As a result of our evaluation of existing sampling practices, we recommend a formal sampling schedule be prepared with the following information:

- Location
- Frequency of sampling
- Type of analyses to be performed
- Remarks as related to special reasoning

Recordkeeping and Reporting System. The laboratory data processing relies totally on manual labor. Considering the amount of data generated and the number of reports prepared on a weekly and monthly basis, we recommend automation of this process to reduce time required for data processing and reduce potential human error in the data transferring process, and facilitate statistical and trend analyses for data intepretation and early identification of water quality problems.

ALTERNATIVES TO CHLORINATION

Concerns about the San Francisco Water Department's disinfection practice are in two areas:

1. The formation of THMs and alternatives to chlorination to lower the THM levels in the distribution system.
2. The safety concern of chlorine gas handling at the City's chlorination stations and alternatives to the use of gaseous chlorine.

Chlorine is currently employed as the disinfecting agent for the San Francisco water supply. Hetch Hetchy supply is chlorinated at the Tesla Portal. Flows from the two Bay Area filtration plants are chlorinated before entering the transmission system. Additional chlorine is also applied at outlets of nine reservoirs located in the City.

The level of THM, however, increased after chlorination at Tesla Portal and the treatment plants and increases along the transmission routes. The levels are highest in the City distribution system after chlorination at the City's reservoirs. The average level, based on the quarterly report to the State Department of Health Services, reaches 75 ug/L, which is lower than the regulated limit of 100 ug/L. In light of the more stringent THM standards suggested by the EPA, alternative disinfection methods need to be evaluated to lower the THM levels.

Alternative methods of disinfection, including chlorination, are evaluated and discussed in Chapter 7 of this report. They are:

- Chlorine disinfection - chlorine gas
  sodium hypochlorite
- Chloramine disinfection
- Chlorine dioxide
- Ozone

Comparison of Alternatives

Precise comparisons of alternatives require testing of these processes. The probable ranking of the four alternatives in regard to cost and oxidizing power is:

Ranking*	Oxidizing potential	Cost
1	Chlorine	Chlorine
2	Ozone	Cloramines
3	Chlorine dioxide	Chlorine dioxide
4	Chloramines	Ozone

*Ranking in order of preference.

If the use of chlorine alone were to be precluded because of the THM potential, chloramines would be the most cost-effective alternative. The Water Department is presently conducting a treatability study using chloramines. Bench scale tests support the conclusions that chloramines are less effective as a disinfectant if fed at Tesla Portal where the pH of water is in the range of 9 to 10. The feasibility of relocation of the disinfection station upstream from Rock River lime station needs to be assessed. The City is also required by the DOHS to conduct pilot programs of chloramine disinfection in selected areas to evaluate the effectiveness of the process on a larger scale before full implementation of the switch.

If the result of the chloramine study suggests negative impacts such as the taste and odor problems that are being experienced by some water utilities, seasonal shutdown of the ammonia feed system may be necessary.

Pending the outcome of the chloramine study, the City can proceed to study the cost effectiveness of the selection between chloramine and chlorine dioxide. In any consideration of the chlorine dioxide process, the location and explosion potential must be included.

Costs have been estimated for both the capital improvements and the annual cost of chemicals for the conversion of disinfection systems.

Location	Chloramine	Chlorine dioxide
Sunol filtration plant	$125,000	$100,000
San Andreas filtration plant	125,000	100,000
Tesla Portal disinfection station	150,000	115,000
	$400,000	$315,000

The facilities for the San Andreas plant were sized for anticipated expansion of that plant.

Annual costs for chemicals for chlorination compared to the chloramine and chlorine dioxide alternatives have been estimated:

Location	Chlorine*	Chloramine	Chlorine dioxide
Sunol filtration plant	$ 50,000	$ 80,000	$ 300,000
San Andreas filtration plant	20,000	32,000	122,000
Tesla Portal disinfection station	102,000	163,000	614,000
	$172,000	$275,000	$1,035,000

*1982 estimates.

It is obvious that the cost of adding the necessary capital improvements would be somewhat insignificant compared to the cost of chemicals.

Based on these analyses, we recommend the City continue the current chloramine study program and proceed to conduct the pilot scale testing as planned. If the results are favorable, we recommend an engineering feasibility study be conducted to evaluate the cost effectiveness of converting the Tesla Portal facility to chloramines as compared to relocating the

disinfection station to a feasible site above Rock River, possibly Moccasin. The cost of a new station will be in the range of $400,000 to $500,000.

If the conversion to chloramine proves feasible and is installed at Tesla Portal and the two treatment plants, the City should conduct a testing program to evaluate the behavior of chloramine residual throughout the system. If maintaining the residual along the Peninsula becomes a problem because of the long travel time or taste and odor problem, the City should consider the conversion of Casey Quarry to chloramine feed. This conversion would cost approximately $400,000. With a second feed point, the residual level in the City may be maintained and the use of the City chlorination stations eliminated.

In case chloramine disinfection is demonstrated to be unacceptable, bench scale and pilot scale testing should be performed on the use of chlorine dioxide.

When considering the safety issue related to the City's chlorination practice within the City distribution system, the only practical alternative is the use of sodium hypochlorite. Some of the City stations do not lend to conversion without relocation. The cost of conversion is estimated to average $30,000 for a small station and $60,000 for each of the two large stations. Other concerns with respect to the conversion include:

- Increased truck traffic to the stations for solution transportation. Tank cars will be used instead of pickup trucks for chlorine delivery.
- Increased sodium level in drinking water may be a health concern for individuals with hypertension.

- The storage requirement for sodium hypochlorite at some stations may be large and require plastic lined or fiberglass tanks. The safety of these tanks to resist earthquakes is a primary concern.

- Cost of sodium hypochlorite is higher than that of chlorine. Diluted solution at 12.5% has a short shelf life. Effectiveness of chlorination will diminish with time.

Recognizing the safety precautions that are being exercised at the City chlorine stations, we have concluded that the best alternative will be to retain the current practice. Increased storage at each station will decrease the frequency of chlorine handling and also reduce the number of delivery trips through the neighborhood.

If the chloramine disinfection study proves feasible and supports the effectiveness of maintaining chlorine residual throughout the system, the City's chlorine facilties may not need to be operated in the future and this safety concern will be eliminated.

Chapter 1
INTRODUCTION

AUTHORIZATION

On October 6, 1983, the Public Utilities Commission, City and County of San Francisco, authorized Metcalf & Eddy, Inc. to review the water quality management program of the San Francisco Water Department.

The work to be performed under the contract agreement dated July 26, 1983, consists of an assessment of the San Francisco Water Department's organizational efficiency and effectiveness in the following areas:

1. Raw Water Quality Control. Security, sanitation, and quality controls at all Water Department local terminal reservoirs located in Alameda, San Mateo, and Santa Clara counties.

2. Operation of Filtration Plants. Adherence to all applicable standards for operations, maintenance of records, technological training, and plant performance at San Andreas and Sunol filtration plants.

3. Quality Control in Distribution System. Effectiveness of (a) disinfection programs: adherence to applicable standards covering bacteriological matter, THM formation, other volatile organic matter, contaminants, asbestos, etc.; (b) cross-connection control program; and (c) corrosion control program.

4. Operation of Laboratory. Effectiveness of all testing programs and adherence to required standards, maintenance of records, and technological training.

5. Alternatives to Chlorination. Desirability of conversion to sodium hypochlorite and chloramine.

For each of these areas, recommendations will be made on necessary improvements, including:

1. Estimates of time required to implement the recommendations.

2. Estimated costs, both capital costs and operation and maintenance costs of implementing the recommendations.

3. Staffing requirements and personnel changes to implement the recommendations.

4. Justification of benefits to be derived from each recommended improvement and/or the consequences of not implementing the change.

A detailed task breakdown is presented in Appendix A.

BRIEF DESCRIPTION OF SAN FRANCISCO WATER SYSTEM

The following paragraphs are a brief overview of the San Francisco water system to provide a background for the study.

Sources of Supply

The principal sources of water supply for the City of San Francisco are watersheds in the Yosemite Park area of Tuolumne County, watersheds in Alameda and Santa Clara counties, and watersheds relatively close to the City in San Mateo County. A simplified map of the system is shown in Figure 1-1. Reservoir impoundments have been constructed in the development of these watersheds as follows:

Area	Division	Reservoir
1. Yosemite	Hetch Hetchy	Hetch Hetchy Lake Eleanor (emergency) Lake Lloyd (emergency)
2. Alameda and Santa Clara counties	Alameda	Calaveras San Antonio

Area	Division	Reservoir
3. San Mateo County	Peninsula	Crystal Springs San Andreas Pilarcitos

The Alameda and Peninsula reservoirs are used essentially for water supply. The Hetch Hetchy system serves multipurposes: power generation, irrigation, as well as water supply. At the present and projected water demand rates for San Francisco, Hetch Hetchy is the major source of water for the City system.

Permission to develop the Hetch Hetchy system was originally granted to the City with the provision that certain downstream quantities be released from the reservoir to meet irrigation needs. More recently, Don Pedro Reservoir was constructed downstream from Hetch Hetchy on the Tuolumne River to serve essentially irrigation needs. The City participated financially in this project to gain certain rights and privileges. When water must be released from the Hetch Hetchy system to adjust reservoir levels, the release flows to Don Pedro Reservoir. The City also has the right to use Don Pedro as a source of supply in emergency. This use would, however, require pumping to deliver flow to the Nob Hill Tunnel transmission line to the City, and the pumping facilities have not yet been installed.

Transmission/Hydraulics

Transmission of the water supply to the City starts at Moccasin Regulating Reservoir, a small impoundment that receives the tail race discharge from Moccasin Powerhouse. This power facility is the furthest downstream in the Hetch Hetchy power generation system. Outlet from Moccasin Reservoir flows into the Foothill Tunnel constructed in rock. There is a pipe that leads directly from the turbine tail race to the tunnel inlet bypassing Moccasin Reservoir. This line alone cannot, however, carry the higher flow requirements. Overflow from Moccasin Reservoir enters Don Pedro Reservoir.

At the downstream Oakdale Portal, the Foothill Tunnel discharges into a battery of three parallel steel pipelines, 60-in., 62-in., and 78-in. in diameter. At Tesla Portal, the flow enters the Coast Tunnel which extends to the Irvington Portal in Alameda County. About 5 miles upstream from this location, three siphons carry tunnel flow under Alameda Creek. Connections are provided in one of these system lines to permit pumping Hetch Hetchy flow to San Antonio Reservoir. Connection is provided in a second of these system lines to receive the treated water flow from the Sunol filtration plant. The pump/piping system also provides for pumping flow from San Antonio Reservoir to the filtration plant and for routing Calaveras Reservoir water to San Antonio Reservoir.

At the west portal, the transmission of flow to the City divides into two separate paths. One route, with two parallel lines including sizes ranging from 72 to 96 inches in diameter, goes around the south end of San Francisco Bay through Sunnyvale, Mountain View, and Palo Alto. The other route goes almost directly west across the bay. This transmission route also includes two parallel lines of 60- and 66-inch size. The two sets of pipelines again join at the entrance to Pulgas Tunnel just west of Redwood City.

Originally, Pulgas Tunnel emptied into Crystal Springs Reservoir. To avoid the mixing of Hetch Hetchy water with lower quality Crystal Springs water, a bypass of the reservoir was constructed in 1968. A flow balancing reservoir was also constructed to provide that function formerly available with Crystal Springs Reservoir in the flow path. The Hetch Hetchy flow, supplemented by contributions from the sources across the bay, now can be pumped to the balancing reservoir or can flow by gravity either to Crystal Springs Reservoir or north into the City supply system.

San Andreas Reservoir has a maximum water level elevation some 165 feet above that of Crystal Springs. The Crystal Springs pump station can take suction from Crystal Springs Reservoir or the bypass tunnel for delivery to San Andreas Reservoir. Water from this higher storage facility is pumped to the San Andreas filtration plant for treatment before flowing to the transmission system leading to the City. Water from storage in Pilarcitos Reservoir and intercepted flow from San Mateo Creek are also diverted by gravity to San Andreas Reservoir.

Chapter 2

REGULATORY REQUIREMENTS AND PUBLIC HEALTH CONSIDERATIONS

CURRENT REGULATORY REQUIREMENTS

The current standards for drinking water applicable for the San Francisco water quality supply are those established by the USEPA and modified by the California Department of Health Services. The regulations are divided into two principal categories: Primary Drinking Water Standards and Secondary Drinking Water Standards which have to be met by all public water supplies unless exempted. Primary Drinking Water Standards pertain to those consitutuents that present a risk to health when the water is used for drinking or culinary purposes. Secondary Drinking Water Standards pertain to those constitutents that may be objectionable to an appreciable number of people but are not generally hazardous to health.

Under present statutes, the USEPA established the minimum contaminant levels for constituents of concern. The state regulatory authority may adjust maximum contaminant levels of such constituents to lower, more stringent requirements. The American Water Works Association (AWWA) has also established quality goals for the industry that are even more stringent than the federal and state standards. These are, however, suggested goals and not mandatory. The AWWA constituent levels are attainable with current treatment methods, but usually only with optimized process control.

A summary of historical water quality data for treated water is included in Table 2-1. The treated water, including the unfiltered water from the Hetch Hetchy system that is routinely delivered to the distribution system, meets in every respect the current legal water quality standards of the USEPA and the State of California Drinking Water Regulations.

Table 2-1. SUMMARY OF HISTORICAL WATER QUALITY DATA
PUBLIC HEALTH CONSIDERATIONS

Constituent[a]	Applicable California standards	Alameda East Portal	Sunol Valley WTP	San Andreas WTP
Inorganic chemicals - Primary Standards				
Arsenic	0.05	<0.01	<0.01	<0.01
Barium	1.0	<0.5	<0.5	<0.5
Cadmium	0.01	<0.002	<0.002	<0.002
Chromium (total)	0.05	<0.01	<0.01	<0.01
Fluoride	1.4-2.4[b]	<0.02	0.10	0.94
Lead	0.05	<0.02	<0.02	<0.02
Mercury	0.002	<0.0005	<0.0005	<0.0005
Nitrate	45	0.2	2.0	0.2
Selenium	0.01	<0.01	<0.01	<0.01
Silver	0.05	<0.01	<0.01	<0.01
Organic chemicals[c] - Primary Standards				
Endrin	0.0002	<0.0001	<0.0001	<0.0001
Lindane	0.004	<0.0001	<0.0001	<0.0001
Methoxychlor	0.1	<0.0002	<0.0002	<0.0002
Toxaphene	0.005	<0.0002	<0.0002	<0.0002
2,4-D	0.1	<0.001	<0.001	<0.001
2,4,5-TP (Silvex)	0.01	<0.001	<0.001	<0.001
Total trihalomethanes	0.10	--[d]	--[d]	--[d]
Radiological parameters[c], pc/L- Primary Standards				
Gross alpha	15	<3	<2	<3
Gross beta	50	4	6	4
Radium 226 and 228	5	—	--	--
Strontium 90	8	<2	<2	<2
Tritum	20,000	<1,000	<1,000	<1,000

Table 2-1 (Concluded)

Constituent[a]	Applicable California standards	Alameda East Portal	Sunol Valley WTP	San Andreas WTP
Microbiological[d] - Primary Standards				
Coliforms, No./100 mL	None	<1	<1	<1
Consumer acceptance limits - Secondary Standards				
Color, TCU[e]	15	0	0	0
Copper	1.0	<0.02	<0.04	<0.02
Iron	0.05	0.05	0.07	0.08
Manganese	0.05	<0.02	<0.02	<0.02
Foaming agents (MBAS)	0.5	<0.05	<0.05	<0.05
Turbidity, TU[e]				
Filtered	0.5	—	0.10	0.10
Unfiltered	1.0	0.40	—	—
Zinc	5.0	<0.02	<0.02	<0.02
Mineralization - Secondary Standards				
Specific conductance, umhos[e]	900	43	250	138
Chloride	250	3	17	12
Sulfate	250	1.6	20.8	10.4
Total dissolved solids	500	31	162	86
Miscellaneous constituents				
Alkalinity	—	16	89	41
Aluminum	—	0.03	0.04	0.03
Calcium	—	5.9	27.4	12.7
Hardness	—	17	104	50
Magnesium	—	0.4	8.6	4.4
pH, units	—	8.9	8.2	8.2
Phosphate	—	0.02	0.07	0.02
Potassium	—	0.05	1.9	0.7
Sodium	—	2.5	14.0	9.3

a. Concentrations in mg/L, unless otherwise noted.
b. Value varies depending on temperature.
c. Results from most recent sampling period.
d. Running 4-month average multipoints in system: low 0.033; high 0.092.
e. Historical averages.

ANTICIPATED CHANGES IN REGULATIONS

Under the provisions of the Safe Drinking Water Act, the federal government (USEPA) can amend the primary drinking water regulations as necessary to protect the health of the public. Either maximum contaminant levels or treatment techniques can be established.

The USEPA currently has an Advance Notice of Proposed Rules Making (ANPRM) published (October 1983) that announces its intention to propose National Revised Primary Drinking Water Regulations for organic, inorganic, microbial, and radonuclide contaminants in drinking water. A comprehensive reassessment will be made of the current (interim) regulations directed toward identifying chemicals in drinking water for which drinking water regulations would be warranted. Should changes ultimately be made, the states, such as California, having primacy would be mandated to adopt the new regulations also. A state could adopt more stringent regulations if it wanted.

The purpose of an ANPRM is to solicit public comment on the regulations and their technical and regulatory issues that are being examined. The USEPA plans a detailed assessment of (1) the experiences since application of the interim regulation (1975); (2) occurrence, frequency, and human exposure potential of contaminants in drinking water; (3) human health concerns and basic toxicology; (4) water treatment technologies and costs; and (5) analytical chemistry and monitoring methods and implementation options that would optimize public health protection without unnecessary economic burdens on the states and communities.

A three tiered approach has been developed for determining whether and in what manner to regulate specific contaminants. Drinking water contaminants would be developed into categories for regulatory purposes.

Category I	Those which occur with sufficient frequency and which are of sufficient concerns to warrant national regulation (MCL) and consistent monitoring and reporting.
Category II	Those which are of sufficient concern to warrant national regulation (MCL) but which occur at limited frequency, justifying flexible national minimum monitoring requirements to be applied by state authorities.
Category III	Those which would not warrant development of a regulation but for which nonregulatory health guidance could be provided to state water systems.

Within this framework, specific contaminants that are being considered for inclusion in the Revised National Primary Drinking Water Regulations are noted in Table 2-2.

It is in the interest of the City of San Francisco to become thoroughly familiar with the USEPA ANPRM since some of the considerations, if enacted by USEPA, could have profound economic impact on the operation of the City's water system. Of particular concern to the City is the USEPA proposal to consider the inclusion of maximum contaminant levels for Giardia lamblia and asbestos and to review the need of lowering the current turbidity standard. A discussion of these contaminants as they relate to the City of San Francisco is presented. Recommendations on future facilities improvements to meet the anticipated changes in regulations are incorporated in the following chapters.

Table 2-2. CONTAMINANTS UNDER CONSIDERATION FOR ADDITION TO OR MODIFICATION OF NATIONAL PRIMARY DRINKING WATER REGULATIONS

Microbiological and turbidity

Coliforms and turbidity
Giardia lamblia
Viruses
Standard plate count
Legionella
Filtration treatment for surface water
Disinfection requirement

Inorganic chemicals

Aluminum
Antimony
Asbestos
Beryllium
Copper
Cyanide
Molybdenum
Nickel
Sodium
Sulfate
Thallium
Vanadium
Zinc

Synthetic organic chemicals (SOC)

Acrylamide
Adipates
Alachlor
Aldicarb
Altrazine
Carbofuran
Chlordane
Dalapon
Dibromochloropropane (DBCP)
Dibromomethane
Dinoseb
Diquat
Endothall
Epichlorohydrin
Ethylene dibromide
Glyphosate
Hexachlorocyclopentadiene
PAH
PCB
Pentachlorophenol
Phthalates
Simazine
Toluene
Vydate
Xylene
1,1,2-Trichloroethane
1,2-Dichloropropane
2,3,7,8-TCCD (dioxin)

Radionuclides

Multiple exposures
Radon
Uranium

Recommendations

To meet future more stringent requirements on turbidity, Giardia lambia, and/or asbestos, it would be necessary to filter all of the Hetch Hetchy supply. Since the USEPA proposed regulations are still in promulgation, enforcement dates cannot be projected.

The Water Department has evaluated the needs for the total treatment of its water supply. The addition of the 40-mgd Crystal Springs treatment plant and the expansion of the 40-mgd San Andreas plant to 80 mgd have been planned. Design and construction of these facilities will proceed when the bond election for its funding is approved by the voters of San Francisco.

The filtration of the Hetch Hetchy water has been planned to be located near the Sunol plant. We recommend the Water Department proceed with pilot plant studies on the Hetch Hetchy water. The purpose of the pilot study will be to evaluate alternative treatment processes and select the most cost-effective process for future implementation.

The pilot study may consist of two phases. In the first phase, studies will be conducted on alternative processes and the best alternative will be selected. If a filtration process other than granular media filters is selected, the second phase will be the design, construction, and operation of a 1- to 2-mgd demonstration plant to evaluate the selected process. In recent years, water treatment technologies have advanced to include many new state-of-the-art processes. The City of New York has selected ozonation-diatomaceous earth filtration for its Croton water supply for its ability to be mothballed during periods of excellent water quality. Los Angeles Water & Power has selected ozonation-high rate-deep bed filtration for its Owens Valley supply to minimize the capital investments.

Recognizing the excellent quality of the Hetch Hetchy water, some of these new technologies should be evaluated; a 20 to 30% cost savings may be appreciated. A pilot study should be conducted for a year to cover seasonal water quality changes. The cost of the Phase 1 pilot study will be approximately $500,000. This estimate includes operation labor and materials for pilot plant construction. Laboratory support is assumed to be provided by the Millbrae laboratory and is not included. The Phase 2 study cost and duration will vary depending on the process selected.

PUBLIC HEALTH CONSIDERATIONS

The public health considerations related to water supply systems permeate every aspect of a system's operation--from the source of supply, storage reservoirs and transmission mains--through the treatment plant and distribution system--to the ultimate tap of the consumer. It is the responsibility of the federal and state governments to regulate the quality of water that is produced by community water supply systems for the protection of the public's health. A state that has been delegated primacy for the regulation of community water supplies must, as a minimum, enforce the National Interim Primary Drinking Water Regulations and may have regulations more stringent than those promulgated by the federal government. The State of California has been delegated primacy for regulation of its community water supplies. This responsibility is carried out by the Department of Health Services, Sanitary Engineering Branch. The regulations enforced by the State of California are essentially the same as the federal regulations.

As indicated in Table 2-1, the finished water quality of the San Francisco Water Department consistently meets all prevailing drinking water regulations. However, obtaining required results in terms of delivered water quality may not always be the true measure of the adequacy of a water system's operations in terms

of protecting the public's health. Consideration also must be given to the manner and thoroughness by which the effort is pursued. When this consideration is included in the conduct of activities, both efficiency and consistency in operation of the system are more readily assured.

Turbidity

Turbidity is an indicator of the presence of suspended particulates in a water supply which in turn serves as an indicator that harmful substances may be present. The current drinking water regulations rely on turbidity as one measure of treatment efficiency in meeting existing standards. The national standard for turbidity in water distributed to the consumer is 1 turbidity unit (TU) (up to 5 TU for unfiltered water). Turbidity monitoring is required daily for systems using surface water supplies.

The State of California requires that "surface waters exposed to significant sewage hazards, or significant recreational use shall receive as a minimum, pretreatment, filtration and disinfection." The filtered water turbidity, for those sources measured daily, shall be less than 0.5 TU on a monthly average for an acceptable level of public health protection. Otherwise, a 1.0 TU is allowed. The American Water Works Association recommends a goal of 0.1 TU. This goal can generally be obtained by a well designed and operated water filtration plant. Discussion at the national level is now focusing on whether either of the standards (national standard of 1 TU or California standard of 0.5 TU) is low enough. The USEPA/American Society of Microbiology workshop participants (1981) concluded that the present turbidity standard should be retained. However, a treatment goal of 0.2 TU should be established as guidance for filtered water to protect against a breakthrough of Giardia cysts. Along with other measurements (total coliforms, disinfectant residuals, and standard plate counts), the workshop

recommended routine monitoring of turbidity of water in the distribution system.

In addition to using turbidity for measurement of normal particulates in water (1.0 TU), and as a measure for effective removal of Giardia cysts (0.2 TU), turbidity serves as a measure of acceptable reduction of asbestos in water supplies that have been properly pretreated and filtered. The recommended standard for reducing asbestos concentrations is 0.1 TU. From the foregoing, it is seen that the discussion on turbidity centers on lowering the standard in treated water to different levels depending on the quality of the raw water to be treated.

The 1979 report on the Water Department system stated that turbidity was the only sampled parameter that ever exceeded federal or state water standards. Even so, this occurred less than 5% of the time. Filtered water represents about 20% of the water delivered to the distribution system. A 1982 report on San Francisco's water contained a summary of historical water quality data that showed that a level of 0.1 TU was obtained in the Sunol Valley and San Andreas water treatment plant's finished water, whereas, treated water at the Alameda East Portal averaged 0.4 TU; raw water in Pilarcitos Reservoir averaged 1.5 TU; and the Crystal Springs Reservoir averaged 1.5 TU. These data attest to the need for processing all San Francisco water through a properly designed and operated water filtration plant if a standard of 0.1 TU is established, either by regulations or by City policy, for all water delivered to the distribution system.

Coliforms

Coliforms are a group of strains of bacteria that are indicator organisms of pollution or contamination by human wastes. Low level coliforms are found in most of the surface water supply sources in the San Francisco system. With proper disinfection of the water prior to delivery and a monitoring program, coliforms

are easily destroyed to provide adequate protection of public health.

Giardia Lamblia

Giardia lamblia is a protozoan that is a human intestinal parasite and is the cause of giardiasis, a disease that can be mild or extremely debilitating. Giardia infections can be acquired by ingesting viable cysts from food or water. Several outbeaks of giardiasis have been traced to municipal water supplies. Humans and both wild and domestic animals have been implicated as hosts.

At the present time, the USEPA has not identified a simple or reliable method for assaying Giardia cysts in water samples. Giardia cysts are relatively resistant to chlorine. The effectiveness of chlorine at killing cysts of Giardia depends on many factors including the chlorine demand, temperature and pH of the water, the concentration and type of chlorine residual, and the chlorine contact time. Preliminary evidence indicates that cysts can be killed at warmer temperatures, e.g., 20^{o}C with 1.5 mg/L chlorine for 10 minutes. At a temperature of 5^{o}C and 2.5 mg/L of chlorine, 60 minutes is required to obtain a 99% kill.

Current information (USEPA) suggests the infective dose of Giardia cysts for humans is one to ten. This low infection dose increases the importance of providing adequate disinfection of a water supply. Giardia cysts may be present in surface water in a low concentration. However, cyst presence still poses a health hazard. Filtration, whether through diatomaceous earth or granular media, has been shown to be the most consistent and effective method for removing cysts of Giardia from community supplies.

Studies undertaken (1982) by the University of California at Davis cooperatively with the National Park Service have indicated

a reservoir of Giardia cysts on the Tuolumne Meadows area of the Hetch Hetchy watershed. Pending the outcome of the Giardia study, the State Health Department may require filtration of the Hetch Hetchy water supplied to the communities of Early Intake and Moccasin, since no other treatment is used to provide adequate protection against potential waterborne giardiasis for water users in these communities.

No outbreaks have occurred in the Hetch Hetchy watershed or in the San Francisco Water Department service area that can be traced to drinking water contamination. However, it must be recognized that there is no simple and reliable method for assaying Giardia cysts in water samples. It is anticipated that new techniques, such as chemiluminescence which is being developed by the California State Health Department laboratories, will provide a more effective and efficient analytical tool. Under the current circumstances, it is not possible to be certain that water supplies are or are not implicated in the transmission of giardiasis unless a significant outbreak occurs. This uncertainty may be one of the reasons for the growing measure of support for requiring filtration of all surface water supplies.

Presently, the USEPA is giving serious consideration to establishing a treatment technique requirement consisting of filtration and disinfection of all surface water supplies. There is reason to believe that the California State Health Department would support establishment of such a standard.

Asbestos

Asbestos occurs frequently in drinking water both from natural mineral sources and from the degradation of asbestos-cement water pipes in contact with aggressive water. While airborne asbestos is a recognized health hazard, the effect on human health of asbestos ingested from drinking water is unclear. The role of asbestos in the etiology of gastrointestinal cancer has been a

matter of scientific controversy. According to the USEPA ANPRM (1983), the most recent animal feeding studies have not shown any adverse health effects from ingestion of asbestos fibers. The epidemiology data on the occurrence of gastrointestinal tract cancer among occupationally exposed persons appears to be the most relevant issue relating risks from ingestion of asbestos from drinking water. In view of these data, even though the risk appears to be low, a continuing concern exists with respect to asbestos in water supplies.

A past study (1979) of the San Francisco Water Department reported asbestos concentrations of 6.6×10^7 fibers per litre for the Crystal Springs Reservoir, 20×10^6 for San Andreas Reservoir, and 1.1×10^8 fibers per litre for the Calaveras Reservoir. The same study indicated asbestos concentrations in Hetch Hetchy water upstream of Crystal Springs Reservoir of 1.0×10^5 to 4×10^5 fibers/litre. The minimum detectable asbestos level is between 1×10^4 and 1×10^5 fibers/litre.

The concentration of asbestos in raw water sources can be reduced to below detectable limits by modified conventional coagulation and filtering techniques. Filtration alone is ineffective for this purpose because of the small size of asbestos fibers. As a practical guide, water that has been pretreated and filtered and contains 0.1 TU or less is considered to have received acceptable treatment for reducing the number of asbestos fibers in drinking water.

Calaveras Reservoir water is treated at the Sunol Valley filtration plant and San Andreas Reservoir water filtration plant. The Water Department adjusted the operations at both of these filtration plants in 1979 to improve removal of asbestos fibers from drinking water supplies. Since that time, a recent report (1982) stated that the turbidity of the water treated at these facilities and discharged to the distribution system has been maintained at or below 0.1 TU. Water from the Crystal

Springs Reservoir is not always processed through the San Andreas water filtration plant. Since 1980, by Water Department policy, no unfiltered Crystal Springs water will be used except in emergencies.

When the source of asbestos is the deterioration of asbestos-cement pipe in contact with aggressive waters, calcium carbonate saturation of the water is effective in protection of the pipe. Other treatments for inhibiting deterioration of asbestos-cement pipe include use of zinc corrosion inhibitors, pH adjustment, and lime stabilization.

While the City of San Francisco is reported to use very little asbestos pipe, this pipe is used often by many of the surrounding communities that distribute water treated by the San Francisco Water Department. It is reported that cement pipe constitutes from 40 to 100% of the distribution system of these communities. Reported survey results (1979) have shown a significant increase in the number of fibers in systems after water flowed through the pipe (1.7 to 4.3 x 10^5 fibers/litre before, compared to 5.3 to 8.9 x 10^6 fibers/litre after). Reports provided by the State Health Department showed fiber counts at monitored points in the water system of 1.6 x 10^7 to 3.8 x 10^7 in 1977. Neither of these studies may be reflective of conditions in the system as they exist today. The City does provide pH control of the Hetch Hetchy water by the addition of lime at Rock River.

Routine determinations of the Langlier index (or other acceptable index) and pH are being made at representative sampling points throughout the distribution system. Periodically, counts should be made of the asbestos fibers in the system when the corrosion index suggests that expected control levels are not being maintained.

Overall, one can conclude that actions taken by the Department to reduce the levels of asbestos fibers in the water consumed by the public are in consort with the recommendations of the federal and state governments. The expressed statement of the State Health Department is "...it is prudent for water utilities to take appropriate actions to minimize the amount of asbestos occurring in each water supply." The step that could be taken to provide optimum compliance is a policy by the Department that would require filtration of all water prior to delivery to the distribution system together with the effective implementation and evaluation of the corrosion control and monitoring program. Recommendations for future actions are discussed in later chapters.

Trihalomethanes

Laboratory tests have indicated that trihalomethanes (THM) may also be carcinogenic. Trihalomethanes are formed by the reaction of free chlorine with certain natural organic substances found in certain surface waters. The primary source of these organics is the decay of algae and other plant life either found in reservoirs or washed down into reservoirs and streams. San Francisco does use chlorine as a disinfectant in water treatment.

It is important to remember that the extent of THM formation depends on several factors including chlorine concentration and contact time. The time of travel from Tesla Portal (point of chlorine addition) to distant points in the distribution system can take from several hours to 1 to 2 days depending on the number of San Joaquin pipelines in service and the flow passing through the system. A sampling program conducted in 1979 indicated that the THM concentration in water in the transmission system occasionally exceeds the regulated limitation of 100 ug/L. Between the Hetch Hetchy Reservoir and the Irvington Portal, THM concentrations in grab samples ranged from less than

1 to 105 ug/L. West of Irvington Portal, values of 35 to 127 ug/L were reported. Results of quarterly total THM reports (1983) show that some portions of the distribution system carry THM residuals very close to 75 ug/L and sometimes exceeding the 100 ug/L standard (maximum of 122 ug/L). The overall running annual average values of THM (most recent four quarters) for the total system are within the legal limits.

Other Water Quality Constituents

Other water quality constituents concerning public health include lead, sodium, aluminum, herbicides and pesticides, and volatile synthetic organic chemicals.

Lead. Lead is toxic to humans since it tends to be deposited in bone as a cumulative poison. The potential sources of lead contamination in the City water system are the old lead customer connections still in service. Surface waters, like those developed for the City supply, tend to be somewhat corrosive. When the pH of the supply is properly adjusted to above neutral, noncorrosive range, it will be less likely for lead to enter into the water in solution form.

Sodium. If sodium is in too high content in water, it may be harmful to individuals who suffer from high blood pressure or other cardiovascular disorders. The USEPA has considered maximum sodium levels at 20 mg/L, 100 mg/L, and as high as 200 mg/L. Except for a few well supplies still in use in the City system, the sodium contents from the surface water sources are significantly lower than 20 mg/L. However, caustic soda (sodium hydroxide) is used to adjust the pH of San Andreas filter plant product water. It warrants attention that the sodium level in the finished water is not significantly elevated.

Aluminum. Although it has not been definitely established, recent surveys have indicated a possible link between aluminum

content in drinking water and Alzheimer's Disease. Neither the definite link or the levels of aluminum content that might be harmful have been as yet determined. Drinking water standards currently do not contain a limit for aluminum although a maximum level of 0.05 mg/L has been suggested by the AWWA goals. Aluminum sulfate is the primary coagulant used by the City at the two filtration plants for turbidity control. Effective coagulation and flocculation and optimizing of alum dosage in treatment can eliminate the carryover of dissolved aluminum in the product water. The data available from the treatment plants indicate the aluminum levels are below the suggested maximum limit.

Herbicides/Pesticides. These are synthetic organic products used in weed control or pest control in agricultural activities. Tests with laboratory animals have indicated that certain herbicides and pesticides may be carcinogenic to humans. Potentially harmful herbicides/pesticides include endrin, lindane, methoxychlor, toxaphene, 2,4-D, and 2,4,5-TP (Silvex). The full chemical analysis made of the different source streams of the San Francisco supply shows these substances to be nondetectable.

Volatile Synthetic Organic Chemicals. On March 4, 1982, the USEPA issued an advance notice of proposed rule making concerning a proposal to regulate volatile synthetic organic chemicals in drinking water. These chemicals are most frequently associated with groundwater. However, surface water subject to industrial contamination can contain a broad spectrum of synthetic organic chemicals. Because the San Francisco watersheds are relatively well protected and have minimal activities on them, the proposal to regulate these contaminants will have little impact on the Water Department's operations. However, all water systems may be subject to a monitoring requirement to support the conclusion that synthetic organic chemicals are not a contaminant in the water supply.

Chapter 3
RAW WATER QUALITY CONTROL

The San Francisco Water Department depends on several reservoirs for water supply and storage. Quality control at these reservoirs and their watersheds is obviously very important to the maintenance of high quality water.

OBSERVATIONS

Hetch Hetchy Reservoirs

The Hetch Hetchy system includes the main San Francisco water source, Hetch Hetchy Reservoir; two emergency reservoirs, Lake Eleanor and Lake Lloyd; and two regulating reservoirs, Priest and Moccasin.

Hetch Hetchy Reservoir is the principal source of water for the San Francisco system. The watershed itself is within the boundaries of Yosemite National Park and is therefore under the jurisdiction of the Park Service and its rangers. The watershed is used during the summer months by campers and hikers and there is one major campsite at Tuolumne Meadows. This campsite has a small sewage treatment facility; however, the discharge is to an evaporation/infiltration area and is not directly to the river. The popular Yosemite Valley area of the Park is not within the Hetch Hetchy watershed. Sanitation in the Hetch Hetchy watershed is monitored by the park rangers and the watershed keepers of the Hetch Hetchy Division. While they are not responsible to the City, they are interested in maintaining this section of the park as a wilderness area that is consistent with the City's needs for light use of the area. The wilderness designation of the watershed and its ownership by the Park Service reduces the potential for contamination of the area by farming operations, pesticides, or herbicides. Remote possibilities of contamination

by campers are eliminated by downstream chlorination. Communication with the Park Service and the Hetch Hetchy Division is maintained by the Water Quality Division Manager.

There is a potential risk of giardiasis infection from chlorine-resistant cysts carried by small animals such as beavers. However, since the potential risk is not well defined due to limited information, a study is currently underway by the Department of Health Services (DOHS), funded in part by the Water Department.

Lake Lloyd and Lake Eleanor were developed primarily for power generation. The lakes can be used as an emergency water supply but are not ordinarily tied to the water system. Lake Eleanor is within Yosemite Park; Lake Lloyd is outside the park but within the Stanislaus National Forest. The remoteness of these lakes provides little potential for contamination.

Priest and Moccasin reservoirs are regulating reservoirs for the Moccasin Powerhouse. They both have the potential for algae blooms that would cause taste and odor problems in the water. The common control for algae is the addition of copper sulfate to the water before the algae bloom gets established. This treatment is not always possible at Moccasin because of a sensitive fish hatchery downstream on Moccasin Creek. When the planned water supply pipeline construction is completed for the fish hatchery, the algae problem at Moccasin Reservoir will be alleviated by timely application of a sufficient amount of copper sulfate.

The Hetch Hetchy watersheds appear to be well protected from pollution. Land use is light recreational and well regulated; there is no commercial, industrial, or agricultural activity; and the downstream chlorination facilities at Tesla provide adequate disinfection protection.

Terminal Reservoirs

The Water Department has five reservoirs in the Bay Area. Calaveras and San Antonio reservoirs are on the east side in Alameda and Santa Clara counties. Pilarcitos, San Andreas, and Crystal Springs reservoirs are in San Mateo County. Calaveras and Pilarcitos store only the local runoff from their respective drainage areas. The remaining three reservoirs store local runoff and can also receive water from the Hetch Hetchy system to supplement local runoff. Under the terms of the Raker Act that set up the Hetch Hetchy system, the Water Department is required to make full use of its local supplies.

Security and Sanitation. The five terminal reservoirs are owned and patrolled by the Water Department. No recreational activities are allowed on the reservoirs or the adjacent City-owned lands. The City does not own all of the watershed land tributary to the reservoirs, and control over land outside the City's jurisdiction is maintained by county land use plans and informal contacts between the Water Department and local jurisdictions. There are residential sewage disposal systems within the watersheds; they consist of septic tank-leachfield systems. The San Mateo Reservoir watersheds are primarily designated as an ecological preserve and land use is restricted. The Alameda and Santa Clara watershed land use consists of open space, light farming, and low density cattle grazing.

Staff. Watershed security and management are maintained by a staff of watershed keepers. The staff for the Peninsula Division consists of one supervisor and ten watershed keepers. The Alameda Division has a supervisor and six watershed keepers. The staff lives in individual cottages on the watersheds and patrols the areas daily. The basic duties consist of reservoir security, light maintenance, and erosion control. Each watershed keeper files a daily report of his inspection and files maintenance

requests as necessary. The watershed keepers report to the Suburban Division assistant managers for maintenance and surveillance but report to the manager of Water Quality on security. The Water Department has requested the Civil Service to upgrade the qualifications of the watershed keepers to require training in park management, forestry, and recreation.

Risk Potential. The risk potential of serious problems from the terminal reservoirs is mitigated by the fact that all of the water is filtered and chlorinated at the treatment plants before entering the distribution system. Filtration reduces asbestos content of the raw water and chlorination disinfects the water to greatly decrease disease potential. After treatment, both risks would be very minimal.

The risk of chemical contamination of the reservoirs either through long-term application of herbicides and pesticides on watershed lands in Alameda or a single event such as a spill from a truck into a reservoir has been evaluated. Continuing examination of water quality in terms of these chemicals at the reservoirs will prevent the occurrence of these chemicals in the system. Restrictive application of herbicides and pesticides will prevent their accumulation in the watershed. Water quality management efforts regarding potential toxic spills are being initiated by the Water Department and coordinated with the California Department of Transportation with respect to the Highway 92 crossing at Crystal Springs Reservoir.

The watershed management currently practiced by the San Francisco Water Department is satisfactory for the protection of the raw water sources.

ASSESSMENT AND RECOMMENDED IMPROVEMENTS

Hetch Hetchy Watershed

- In the Yosemite Park area, surveillance provided by the Park Rangers of the watershed area satisfies the City's current needs.
- Since there will be no development permitted on park land, potential for future deterioration of water quality in the Hetch Hetchy due to manmade reasons appears to be minimal.
- The eutrophication process is a natural phenomenom which takes place in all bodies of water. Nutrient materials are washed into the lakes and streams and increase the growth of algae. With increased algae blooms, some water quality deterioration will occur in future years.
- There is some evidence of Giardia cysts in the watershed. However, the potential risk is not well defined and is currently being studied by DOHS.

Storage Reservoirs

- There is no recreation activity or development allowed on City-owned watershed land. The potential of reservoir water quality degradation due to man's activities is minimal.
- The eutrophication process in terminal reservoirs will take place sooner than that of the Hetch Hetchy system due to the different size of the reservoirs.
- Watershed keepers, whose primary responsibility is security and maintenance of grounds, assume the responsibility of water quality surveillance. More formal training and direction are needed in the area of water quality management for watershed keepers.
- Cattle grazing activities on the leased property near Calaveras and San Antonio will not create a significant threat to public health because all waters in these watersheds are impounded in reservoirs and receive complete treatment at Sunol prior to entering the transmission system.
- The only area of water quality concern is at Moccasin Reservoir:
  - The lack of copper sulfate application during summer months results in algae problems.

- State Department of Health Services' concern with Giardia may require filtration of water that is being supplied to the communities of Early Intake and Moccasin.

The watershed management currently being practiced by the San Francisco Water Department is satisfactory for the protection of the sources of raw water.

The only area of water quality concern is at Moccasin Reservoir. With respect to the occurrence of algal problems in the summer months, we expect improvements when the water supply pipeline to the downstream fish hatchery is completed. Timely addition of copper sulfate to the reservoir water should control the algal growth at the reservoir.

Complete bypass of Moccasin Creek is provided to enhance water quality from Hetch Hetchy. Turbidity is being monitored on a 24-hour basis at Tesla Portal. The high turbidity alarm will provide a warning to the water quality manager to take necessary steps for turbidity reduction in the system.

To obtain better control of water quality at Moccasin, we recommend that the water quality at Moccasin Reservoir be closely monitored during the summer months. Grab samples should be obtained on a weekly basis for analysis of plankton counts. The Stationary Engineer at Rock River will be the most logical person to conduct the sampling and to observe seasonal water quality changes at Moccasin. The plankton count analysis can be performed at the Millbrae laboratory.

Pending the outcome of the Giardia Study conducted by the DOHS, the City may be required to provide filtration for the communities of Early Intake and Moccasin. The cost of installing package filtration systems is approximately $50,000 each including chemical feed systems and housing.

Chapter 4
OPERATION OF TREATMENT FACILITIES

On the Hetch Hetchy system, the water is being treated with lime addition at Rock River for corrosion control purposes and with chlorine at Tesla Portal for disinfection purposes. For the terminal reservoirs, full water treatment is provided. The Sunol water filtration plant provides full treatment (alum coagulation, flocculation, sedimentation, filtration, and disinfection) for waters from San Antonio and Calaveras reservoirs. The San Andreas water filtration plant provides full treatment to waters from San Andreas, Pilarcitos, and Crystal Spring reservoirs. In addition, the Water Department provides three alum treatment installations to control runoff turbidity from streams entering the Crystal Springs and San Andreas reservoirs. Three chlorination stations are provided for the Suburban system at Sunol Aqueduct, Peninsula Aqueduct, and Casey Quarry. Also, fluoride for dental hygiene purposes is added to the water delivered north from the Crystal Springs bypass tunnel.

LIME FEED STATION (ROCK RIVER)

The lime feed station is located at the Rock River shaft of the Foothill Tunnel, just upstream from the Oakdale Portal where the Hetch Hetchy system makes the transition from a tunnel to three pipelines. Lime is added to the water supply to raise the pH for corrosion control purposes and to preserve the cement lining of the pipelines.

Observations

The operation consists of storage, slaking, and feed equipment to feed approximately 50 to 60 pounds of calcium oxide per million gallons of water to the tunnel. Rate of feed is set by the Water Quality Division Manager to maintain a pH of 9 to 10 at the end

of the pipelines (Tesla Portal). The pH is read and recorded at Tesla; there is no analysis instrumentation at Rock River. The facility is operated and maintained by a stationary engineer who lives onsite and operates the facility 7 days per week. Maintenance support is provided by Hetch Hetchy from their Moccasin facility.

Inspection of the station showed that the equipment was in good working order and well maintained. The housekeeping was excellent and the operator obviously understood the process and equipment. The station is not equipped with an engine-generator for emergency power.

Assessment and Recommendations

The lime station operation at Rock River is satisfactory to provide the necessary treatment of Hetch Hetchy water for corrosion control. The area of concern is on the question of how much lime is needed to provide proper protection of pipes and the concrete lining of the City's vast water transmission system. The lime feedrate has been determined based on the dosage required to prevent "red water" and has been raised to 55 pounds per million gallons in recent years. Based on our estimates with one set of raw water characteristics at Hetch Hetchy reservoir, it would require a higher level of lime feed. But the desired feedrate should be studied to maintain a positive corrosion index. Recognizing that the pH of Hetch Hetchy water varies over the range of 6.5 to 7.1, and has a very low buffering capacity, lime feedrate should be determined on a weekly or biweekly basis. The stationary engineer can be trained to run simple laboratory tests on conductivity, alkalinity, calcium, temperature, and pH. With established procedures of computation, he can calculate the required amount of lime to bring about a positive corrosion index. The expenditure on training will be about 8 hours; labor requirement on conductivity tests will be 1 to 2 hours biweekly. The investment for a portable pH meter,

conductivity meter, and glassware would be less than $1,000. Considering the amount of investment in the tunnel pipelines and the cost involved in relining aqueducts, we recommend that the lime feedrate be reassessed on a biweekly basis. To effectively stabilize the aggressiveness of the water, the feasibility of adding electrolytes should also be investigated.

While the lime station is operated satisfactorily, there is only one stationary engineer assigned to the post with the stationary engineer at Tesla Portal as relief personnel. We recommend that one additional person be assigned and trained to operate the station as backup. The backup operator can be supported from the Hetch Hetchy Division at Moccasin, or can be assigned from the Sunol filtration plant.

The station is not equipped with emergency power. Although this is not a critical item and the loss of power has not been a frequent experience, the Water Department may consider the addition of backup power or a portable generator to better the operation.

CHLORINE FEED STATION (TESLA PORTAL)

The chlorine feed station at Tesla Portal is the largest chlorination facility in the Water Department system. The station is located at the entrance to the Coast Range Tunnel approximately 30 miles east of the Bay Area. This location allows a long contact time for chlorine disinfection and protects the Coast Range Tunnel from slime growth.

Observations

The operation consists of storage and handling facilities for ton cylinders and the equipment necessary to inject into the system approximately 18 to 20 pounds of chlorine per million gallons of water. The feedrate is set by the Water Quality Division Manager

to maintain a residual of 1 ppm. The residual is checked at the Alameda East Portal. Feedrates depend on the rate of water flow from Hetch Hetchy and time of year. The feedrate is set based on experience and timed by downstream residual readings. Once set, the feedrate tends to be stable until a water flow change is made.

Instrumentation at the station reads and records chlorine feed, turbidity, pH, and system water pressure. The alarm system can transmit local or remote alarms for power failure, low water pressure, low chlorine pressure, turbidity, and positive detection of chlorine in the air. The remote signal is sent to Hetch Hetchy at Moccasin. If the operator is not onsite, he can be reached by a pager system. The station has a standby engine-generator for emergency power.

The facility is operated and maintained by a stationary engineer who lives onsite and operates the facility 7 days a week. Maintenance support is provided by Hetch Hetchy; safety backup is provided by the local fire department; and vacation relief is provided by the operator at Rock River lime station.

Inspection of the chlorination station showed that the operation and maintenance were excellent. Fifteen 1-ton chlorine cylinders were online and nine additional cylinders were available. The building and equipment were spotless and there was no sign of corrosion or deterioration. The operator was well aware of the need for both security and safety. The doors were locked; the windows have security grills; chlorine detectors were operational; and air packs and fire extinguishers were available.

Assessment and Recommendation

The Tesla Portal facility is satisfactory in providing disinfection for the Hetch Hetchy supply. The only area needed to be addressed is the determination of the chlorine feedrate to

maintain desired chlorine residual at the Alameda East Portal. Because the travel time of the chlorinated Hetch Hetchy water through the Coast Range Tunnel increases when the flow of water decreases, the chlorine requirement at lower flows appears to be higher. Because of the variables involved in this operation, the chlorine feedrate determination depends totally on the experience of the Water Quality Manager.

Recognizing that the Tesla Portal facility provides for disinfection of 80% of the City's supply, it is crucial that correlation of the variables be established, and the experience of the Water Quality Manager be documented. Therefore, we recommend:

1. Evaluate the relationship between raw water turbidity and chlorine demand. A correlation curve may be developed by taking turbidity readings and testing chlorine demands at Tesla Portal by the stationary engineer. Training for this simple procedure takes approximately 1 hour; the cost of the chlorine residual apparatus is less than $200.

2. Evaluate the relationship among chlorine feedrate, chlorine residual at Alameda East Portal, and raw water flowrate. A clear correlation may exist between chlorine feedrates and chlorine residuals at different flowrates. This study effort takes special coordination effort by the Water Quality Division. The stationary engineer at Tesla Portal can vary the chlorine feedrate and a stationary engineer from Sunol plant can sample and analyze chlorine residual at Alameda East Portal. It is important that sampling time be closely coordinated. Chlorine residual tests should be performd in the field immediately following sample collection. Data collected should be analyzed, plotted, and interpreted by the Water Quality Manager, the Assistant Water Quality Manager, or the Water Treatment Superintendent.

3. Determine the minimum level of chlorine residual to be maintained throughout the system to provide total destruction of pathogenic organisms in the water system.

The objective of these evaluations is to establish the methodology for determining necessary chlorine feedrates and to maintain more consistent and desirable chlorine residual levels in the treated water.

Presently, relief for the stationary engineer is provided by the stationary engineer at Rock River. It would be more logical to assign a stationary engineer from the Sunol plant as backup.

WATER FILTRATION PLANTS

Sunol Valley Water Filtration Plant

The Sunol Valley water filtration plant, the first of such San Francisco water treatment facilities, was built in two stages. A 40-mgd, nominal capacity plant was constructed in 1965-66. A mirror-image of this plant was completed in 1976 to provide an additional 40-mgd total nominal capacity. Hydraulics of the plant were designed to permit doubling the flow, i.e., to permit a total of 160 mgd to be treated.

The primary purpose of the Sunol plant is to treat water from the developed portions of the Alameda Creek watersheds. Under the Raker Act, San Francisco is obliged to use all of the water from San Antonio and Calaveras reservoirs, City impoundments in the Alameda Creek Basin. Quality of the water from these sources requires filtration to meet the established drinking water standards.

Water from the Hetch Hetchy system can be diverted by pumping for storage to San Antonio. This diversion provides two benefits: (1) the reservoir helps in balancing system flows in the day-to-day operations; (2) the extra storage is then available when needed to supplement flow to the system. The Hetch Hetchy water at this time meets the drinking water quality standards and requires only chlorination and lime stabilization.

Unfortunately, when mixed with the lesser quality storage reservoir waters, filtration is needed.

Treatment Process. The basic purpose of the filtration process provided in the Sunol Plant is to remove particulate matter from the source water. Such particulates include algae, sediment washdown, or amorphic matter, the result of plant and algae decay. The treatment process employed in the Sunol plant may be classified as conventional filtration; the unit processes include:

- Coagulation - alum is added to the water in a flash mixer, to coalesce and agglomerate the particulate solids.
- Flocculation - vertical mixers are fitted with paddles to provide further agglomeration through contact of the solids--to produce larger size floc.
- Coagulant Aid - nonionic and/or cationic polymers are fed to permit reduction of the required amount of the basic alum coagulant and to toughen the floc consistency.
- Settling - after flocculation, the process flow is routed through rectangular basins where the larger-sized solids settle out by gravity.
- Filters - smaller sized particulates, carried over the settling tank weirs, are removed in granular filters filled with dual media--ground anthracite sand.
- Lime Feed - slaked lime is fed to the filter effluent for positive corrosion control.
- Chlorination - chlorine is fed for disinfection.

Provisions are also available to feed activated carbon to remove tastes and odors when required. Hydrofluosilicic acid is added to the process flow for therapeutic purposes (dental cavity prevention).

In the conventional mode of filtration, solids are removed in two stages: settling and filtration. Periodically, accumulated solids collected in the settling tanks must be drained. Filters

must also be backwashed. Sludge lagoons are provided to receive the settling tank blowdown. Washwater ponds are also provided to accept the filter backwash.

Onsite Operations Staff. The onsite Sunol filtration plant has the following permanently assigned operating staff:

Position	No.	Shift assignment
Chief stationary engineer	1	Day
Senior stationary engineer	1	Day
Senior stationary engineer	1	Swing
Senior stationary engineer	1	Day (field)
Stationary engineer	7	Rotated
Stationary engineer	1	Day (field)
Laborer	1	Day
Total	13	

By using stationary engineers for the operator positions, the City gains two advantages under the present civil service regulations: (1) position salaries are commensurate with the assigned responsibilities; (2) the stationary engineer can perform routine maintenance and minor equipment repairs. The operating staff also conduct routine analyses in the plant laboratory for process control. These may include jar tests to determine alum feed requirements, pH determination to check the adequacy of lime stabilization, chlorine residual, and coliform tests for the effectiveness of chlorination.

The Sunol filtration plant is under the overall supervision of a water treatment superintendent who reports to the manager of the Water Quality Division. He is also in charge of the San Andreas treatment plant.

The Sunol plant is manned 24 hours a day. Field personnel noted in the staff listing are used for the operation and routine maintenance of the San Antonio pumping station used to transfer water from that reservoir to the filtration plant. The field personnel may also serve other waterworks facilities remote from

the plant. There is a need to add one senior stationary engineer and one stationary engineer to provide the proper supervision for the rotating shifts.

Outside Service. The permanent staff are assigned essentially operating and routine maintenance duties. All other staff requirements like those for building maintenance major equipment repairs must be furnished from other divisions in the San Francisco Water Department. When painting is needed or when roof gutters must be cleaned of leaves, it is necessary for the filtration superintendent to prepare a work order to apply for such assistance. At present, there is one machinist from the City Distribution Division at the Sunol plant working full time and he has completed a significant backlog of repairs.

Services provided by outside divisions can be a satisfactory arrangement when major machinery maintenance is performed according to manufacturer's recommended schedules. Delays in performing major maintenance can aggrevate into expensive repairs or replacements.

Other outside services are provided by the Water Quality Division laboratory at Millbrae. Samples are taken twice weekly of the source water and product flows and are subjected to a broader scan analysis than is possible at the filtration plant laboratory. Millbrae laboratory personnel collect the samples and conduct the analyses. On the same trip, water samples are collected from the Hetch Hetchy Aqueduct at Rock River, Tesla Portal, and other locations.

Operation Performance. Examination of the records of analyses of the product water flow from the Sunol filtration plant showed that the quality was consistently within the limitations specified in the pertinent regulations. Turbidity was mostly under 0.20 TU and trihalomethanes also meet all current limits.

Inspection of the plant showed the housekeeping habits to be superior; even the floors in the chemical feed areas were relatively spotless. All necessary elements of the plant were in operation. If maintenance was underway, it was being accomplished in a neat orderly manner on standby units.

The most significant feature of the Sunol plant is the size of its operating staff. Assigned staff numbers just 13. Adding the equivalent of outside services provided, the staff might be considered to be 14 or no more than 15. It is not uncommon to see plants of this size, elsewhere in the country, with an assigned staff of more than 30, or more than double the Sunol staff. This unusually small staff size is particularly significant in light of the excellent condition of the plant and its consistently good product performance.

The only problem evident in the plant operation is the apparent need to wait for outside help for building services and major preventive and corrective maintenance. This arrangement can cause delays and result in operational difficulties.

Another noteworthy feature of the Sunol plant operation is illustrated by the comparison of the rated treatment capacity with flow actually handled. In 1982 an average flow of about 68 mgd was treated at the Sunol filtration plant. While the nominal rated capability is 80 mgd, the plant should be able to adequately handle the 160-mgd maximum capacity flowrate. At 160 mgd, the following capacity or rating conditions result.

Flocculation detention, minutes	14
Settling tank detention, minutes	60
Settling tank overflow, gpm/sq ft	1.36
Filter application rate, gpm/sq ft	5

The flocculation and settling tank operating loading rate is somewhat on the high side. The filter application rate is well within the limits specified in modern practice for two stage solids removal in the conventional mode. Any inefficiency due to the high loading rate in the settling tank is being compensated by the filter capacity.

The Sunol Plant is not usually operated at a constant rate in the San Francisco system. More often the plant flow will be varied to compensate for the fill and draw normally provided by balancing reservoirs. Variations in monthly average flows through the plant ranges from 30 to 100 mgd. Daily flow variations are much greater than the monthly average. In effect, the San Antonio and Calaveras reservoirs are used as balancing reservoirs.

San Andreas Water Filtration Plant

For all practical purposes, the San Andreas water filtration plant is a half-size clone of the Sunol plant. Maximum capacity is 80 mgd. The major treatment process units--flocculation basins, settling tanks, and filters--are identical in configuration to the Sunol counterpart. Variations in site features have resulted in some changes in the chemical storage and chemical feed arrangements.

Treatment Process. The predominant differences in the San Andreas treatment operations is that less alum is normally used for coagulation than at Sunol and that caustic soda is used for stabilization instead of lime. Alum use at the San Andreas location is around 15.5 mg/L compared to the 25.6 mg/L average feedrate at Sunol. Other differences exist in the disposal of alum wastes and the fluoridation of finished water. In the San Andreas system, both settling tank underflow and filter backwash are discharged back to San Andreas Reservoir with no treatment. This practice may impact the reservoir ecosystem and water

quality. Alternative sludge disposal methods will be evaluated in the proposed plant expansion project.

Onsite Operations Staff. The onsite San Andreas plant operating staff includes the following

Position	No.	Shift
Chief stationary engineer	1	Day
Senior stationary engineer	1	Day
Senior stationary engineer	1	Swing
Stationary engineers	7	Rotated
Laborers	1	Day
Total	11	

As can be seen, the staff assigned to the San Andreas plant is identical to that for the Sunol plant except for the two field positions at the latter location. There are no offsite responsibilities at the San Andreas plant. Valve operation and pumping stations staff are provided by the Peninsula Division. While the San Andreas plant has half the capacity of the Sunol facility, both plants are being operated with minimum shift coverage. There is also the need to add a senior stationary engineer and a stationary engineer at San Andreas to provide full shift supervision. Duties and the operating routines of the San Andreas staff are the same as at Sunol. This plant is also under the general supervision of the water treatment superintendent who reports to the Water Quality Division Manager.

Outside Services. As at the Sunol plant, all building services and major repair services must be furnished by outside divisions. The effect of the long wait for such services is much more apparent at the San Andreas plant. The atmosphere at the location is often laden with salt carried from the somewhat nearby ocean fog. The salty environment generates rust and paint failure. Outside metal equipment at San Andreas has broken and chipped paint surfaces exposing the rust below. Delay in routine painting at this plant can result in a major expenditure later.

Operations Performance. As in the case of the Sunol plant, the San Andreas operating staff keep their plant in excellent condition. Floors are spotless and the equipment appears to be smooth running. The unsightly and damaged paint surfaces mentioned before are the only flaws that cannot be controlled by the superintendent or the staff. Product water quality consistently meets the turbidity goal of less than 0.20 TU and trihalomethanes are below 100 ug/L.

Monthly San Andreas flow variations are somewhat less pronounced than for the Sunol plant. It is our understanding that the daily flowrates also vary less. Operation of the San Andreas plant is closer to constant flow. The annual average rate of 55 mgd (1982) is closer to the maximum design rate of 80 mgd. This is 69% of maximum rate. At Sunol, the average 1982 flowrate was 68 mgd or about 43% of the maximum treatment capacity.

The flowrate analysis shows that the San Andreas plant and its supply reservoirs are not operated to balance water demand requirements as much as in the case of the Sunol facility. Some significant flow variations do exist.

Assessment and Recommendations

Both Sunol and San Andreas plants are maintained in excellent condition and operate satisfactorily with finished water meeting all latest drinking water regulations on a continuous basis. There is a formal training program to provide the staff with the latest water treatment information and to enhance operation efficiency.

To provide full shift supervision, we recommmend the addition of a senior stationary engineer and a stationary engineer for each plant.

With a relatively small staff, the appearance and effectiveness of these plants suggest good management. The other area that could use improvement at these plants are the ability to provide building and structure maintenance and major preventive maintenance for the mechanical equipment. This can be accomplished by either one of two suggestions:

1. Continue the use of Suburban Division maintenance personnel. A crew of one painter and three machinists should be assigned to work at the treatment plants continuously to perform preventive and corrective maintenance. The same crew should be used to maintain continuity of machinery services.

2. Add a painter for building maintenance and three machinists to perform the necessary duties for both treatment plants.

One other option is to contract outside services through UEB. This arrangement will increase administration costs at UEB. Considering the need is on a continuous basis, it would be more economical to the City to retain this work within the Water Department.

Other Treatment

There are other locations outside of the City distribution system where treatment is provided. These are discussed in the following sections.

Chlorination. In addition to the Tesla Portal and the treatment plants, chlorination of the suburban system is provided at the following locations:

- Sunol Aqueduct
- Peninsula Aqueduct (two locations)
- Casey Quarry (supplemental and emergency)

All of these chlorination stations operate continually except for the Casey Quarry installation. This is a large capacity standby station that is used to supplement chlorination of flow in the Crystal Springs bypass when needed. It is actually in use only infrequently. This standby facility was originally a temporary system to feed sulfur dioxide and is housed in a prefabricated metal building. While this facility is not in service presently, the security and maintenance is marginal and left room for improvement during our visits. The Water Department has taken corrective actions to improve this facility. Security is necessarily important considering the remote location of this building and its light weight construction.

Fluoridation. Fluoridation is applied at the San Andreas water filtration plant and at three other fluoride stations. The major fluoridation station is near the north portal of the Crystal Springs Bypass Tunnel where all flow north to the Peninsula is fluoridated. While the outside of this fluoridation station is attractive, the inside arrangement and condition left much to be desired during our visit. Leaks were evident throughout the building piping system. The hydrofluosilicic acid is extremely corrosive, as evidenced by the rusted steel floor grating and equipment. The four fiberglass reinforced plastic storage tanks are not presently installed in containments. If a tank were to break or leak, the flow would exit the building to the roadway below. The Water Department has included in the 1984-85 budget installation of containments for these storage tanks. A leak detection probe is being installed on the sump.

Reservoir Turbidity Control. There are three alum treatment installations used to control runoff turbidity from streams entering into Crystal Springs and San Andreas reservoirs. Alum is fed at a continuous rate during winter storms. The feed pumps

are activated manually when it is felt that turbidity control is needed. Alum is fed to the stream flow to coagulate and coalesce the particulate matter which is essentially sediment carried in the runoff. The floc formed settles in the bottom of the reservoirs. This practice has been going on for a number of years. Alum used for this purpose in the 1982-1983 water year exceeded one million pounds. A forebay is intended to settle out a considerable amount of alum sludge. Since alum sludge has low density, it is easily upset or stirred up. Overflow to the Crystal Springs Reservoir could cause accumulation of alum sludge and affect the quality of water. Moreover, accumulation of alum sludge may smother bottom organisms important to the ecosystems of the reservoirs. The dissolved aluminum concentration at Crystal Springs Reservoir is 0.09 mg/L as compared to 0.04 mg/L at San Andreas and 0.03 at Pilarcitos. This higher aluminum content may be caused by this practice.

The Water Department has considered discontinuing this practice because Crystal Springs Reservoir water is not being delivered directly to users. The concern for turbidity control has been in the case the reservoir is used to supply the distribution system directly under emergency conditions. Continuing application of alum in these emergency circumstances may improve water quality to be delivered.

Recommendations

The Water Department is presently improving conditions at the Casey Quarry chlorination station and the fluoride station near the north portal of the Crystal Spring bypass tunnel. We recommend the continuation of scheduled improvements and that security at Casey Quarry be checked on a regular basis.

With respect to the alum application to Crystal Springs reservoir, we recommend a more in-depth evaluation be conducted. Previous water quality data, particularly turbidity readings and particle counts at the reservoir outlet, should be correlated with alum applications and the dissolved aluminum concentrations in the reservoir. Additional turbidity readings should be taken during the 1984-85 storm season without the alum application. These data should be compared to evaluate the water quality impact of the alum application. Decisions can then be made regarding the continuation of such practice.

Chapter 5
DISTRIBUTION SYSTEM WATER QUALITY CONTROL

There are three major areas of water quality concern related to the City's water distribution system:

- Chlorine disinfection
- Cross-connection control program
- Corrosion control program

CHLORINE DISINFECTION

The San Francisco Water Department has developed and maintained an extensive chlorination system within the City distribution system for the control of microbiological contaminants. The system provides an adequate level of disinfection, thereby meeting the principal objective of safeguarding the public's health. The bacteriological readings are within current regulations. The use of chlorine as a disinfectant has also met the secondary objectives of suppression of slime growth in the extensive transmission tunnels and "red growths" (iron bacteria) in dead-end lines which amount to approximately 1.5 million linear feet of pipelines.

As stated previously, chlorine reacts with organic compounds to form trihalomethanes (THM) which have been identified as potential carcinogens. The City has evaluated the THM formation potential in accordance with procedures recommended by the USEPA. This evaluation indicated that the potential at City distribution reservoirs is somewhat lower than the potential at the treatment plants and Moccasin Reservoir. The THM level in the distribution system averages about 75 ug/L and is within the regulated limits. The THM levels in the water system are largely related to the chlorination effort at Tesla Portal where a large

quantity of the chlorine is added for disinfection purposes. The city's chlorination stations are only used to maintain desirable levels of chlorine residuals throughout the system. The reduction or lowering of THM within practical limits in the system is achieveable by modifying the process at Tesla Portal and is discussed in Chapter 7, Alternatives to Chlorination.

The San Francisco Water Department's distribution system chlorination stations can be characterized as manual dosage rate, flow-controlled systems in the City. There are nine systems using chlorine gas feed facilities and one with sodium hypochlorite.

Location of Feed

The chlorination stations are located on the highest hills throughout the City to provide proper disinfection to water from each of the terminal reservoirs and to maintain adequate residual throughout the distribution system. Essentially all the locations are in residential neighborhoods with parklike grounds.

Chlorine station location	Chlorination capacity	Chlorine storage
College Mount	One 20 lb/day, one 100 lb/day	Ton container
McCalleran	One 50 lb/day	150-lb cylinder
College Hill	One 50 lb/day	150-lb cylinder
Stanford Heights	One 10 lb/day	150-lb cylinder
Merced Manner	One 75 lb/day	150-lb cylinder
Sunset	One 100 lb/day	Ton container
Sutro	One 75 lb/day	150-lb cylinder
Summit	One 10 lb/day	150-lb cylinder
Lombard	One 20 lb/day	150-lb cylinder

In addition, Lake Merced chlorine station is located at the lakeside end of the Lake Merced pump station. This facility would only be put into use in an earthquake emergency when other sources of water are not available. To minimize the potential of chlorine hazards, there is no chlorine storage on hand. Chlorine can be transported to this station from the Millbrae yard within 2 hours in case of need.

Equipment

All of the City chlorination station facilities are flow paced. A flowmeter automatically regulates the chlorine feedrate to maintain a desired chlorine residual in the water. A level of 1.0 mg/L is sought.

The equipment is typically contained in a concrete structure with the exception of the College Hill station which is housed in a wood shelter; the Water Department is considering converting it to concrete construction for fireproofing. The 150-pound cylinders, or ton containers, are scale-mounted and chained in place. The cylinders are connected to the gas flowrate device by a flexible connector which is pressurized by chlorine gas under normal operation. These stations were constructed during early periods of the system and have provided adequate service for many years.

A water flowmeter on the main is electrically or pneumatically connected to a mechanical device that moves a gas valve to regulate the gas flow. The system is powered by the pressure of the water passing through the device.

A check on the amount of gas used and the amount remaining is provided by weighing the cylinder daily. Cylinders last 5 to 15 days depending on the location. Log books are maintained at each location and records are kept satisfactorily.

Safety equipment routinely provided includes a chlorine leak detector which is connected into a citywide alarm system, a full facemask safety air pack, tools, and repair kits.

The chlorination equipment, visited on a station-by-station basis, was obviously well maintained. The chlorination devices are manufactured by the leading chlorinator manufacturer, of

noncorrosive materials. The City has completed a replacement program in the last 2 years and all chlorinators looked like new. It was evident that the electrical conduits in most of the stations had recently been renewed and that the stations were being painted periodically.

Most of the scales have obviously been in use for many years and are rusty due to the condensation on the chlorine containers, but all scales are in operable condition.

Chlorine Handling and Safety Precautions

Chlorine gas cylinders and containers are trucked to each of the stations. A sanitary engineering technician is assigned to escort each truck delivery as an extra safety precaution.

With the exception of the pressurized gas feedline, which could be improved by using a vacuum feed system or a pressure reducing valve to further minimize leak potential, the chlorine feed systems are satisfactory to provide the services intended.

The stations are equipped with intruder alarm systems. Entry to the station can be made after deactivating the alarm system.

While these stations are unmanned, the alarm signals are sent to the Merced station and dispatchers at Millbrae will be notified; 24-hour coverage is provided.

Recommendations

All of the chlorination stations are being operated and maintained in satisfactory condition. Adequate chlorine residual can be maintained throughout the distribution system for the protection of public health.

The chlorine handling, transportation, and safety precautions are adequate. Each station maintains minimum storage of chlorine gas to reduce the hazard potential to neighbors. However, this practice increases the frequency of chlorine handling and truck traffic. It may be more desirable to provide more storage on hand to minimize handling and consequently reduce the potential for chlorine accidents.

The only area in which improvements are recommended is to eliminate the pressurized gas feed system. The City can incorporate the switch to a new vacuum system in the replacement program or elect to install pressure reducing devices on the gas feedlines. The cost of a new vacuum system will be $2,300 each and the installation of the pressure reducing device will be approximately $1,300 each. We recommend the City modify one station with the pressure reducing feature to evaluate the effectiveness of the conversion. Labor requirements for this conversion will be less than 4 hours.

CROSS-CONNECTION CONTROL PROGRAM

A cross-connection can be defined as any connection or structural arrangement between a potable water supply and any nonpotable source or system through which backflow can occur. Bypass arrangements in plumbing systems or water mains, jumper connections, and other temporary devices through which backflow of contaminated water or fluids can occur are considered cross-connections.

Between 1971 and 1974, statistics indicate that 32% of all confirmed waterborne disease outbreaks involving municipal water systems in the United States were caused by cross connections. This percentage represented the single largest cause for all outbreaks of waterborne disease. Cross connections were again responsible for 47% of waterborne disease outbreaks in municipal water systems in the United States between 1975 and 1976.

The Water Quality Division has in recent years implemented an ongoing cross-connection control program. The program is being coordinated by a senior water inspector as the chief cross-connection officer, assisted by a water inspector and two sanitary technicians. Their duties consist of:

- Coordination of activities on a voluntary basis between the Water Department, the Department of Public Works, and the Department of Public Health.
- Identification of possible cross-connection locations.
- Establishing a testing and retesting schedule for cross-connection control devices.
- Recording of results of field inspections and testing of cross-connection control devices.
- Establishing and maintaining a list of acceptable cross-connection control devices and certified cross-connection control device testers.
- Providing information to property owners and the general public regarding requirements for cross-connection control devices.
- Review of applications for new service and alterations to existing service connections to determine if cross-connection control devices are required.

The current cross-connection control program is a citywide effort involving also the Department of Public Works and the Department of Public Health (Figure 5-1). The Water Department is responsible for the largest share and is currently taking the lead role.

The Water Department is currently monitoring all industrial users, hospitals, and high rise buildings. Schools and Caltrans facilities are planned for inspections in the near future. Inspections will also include the San Francisco Port Authority.

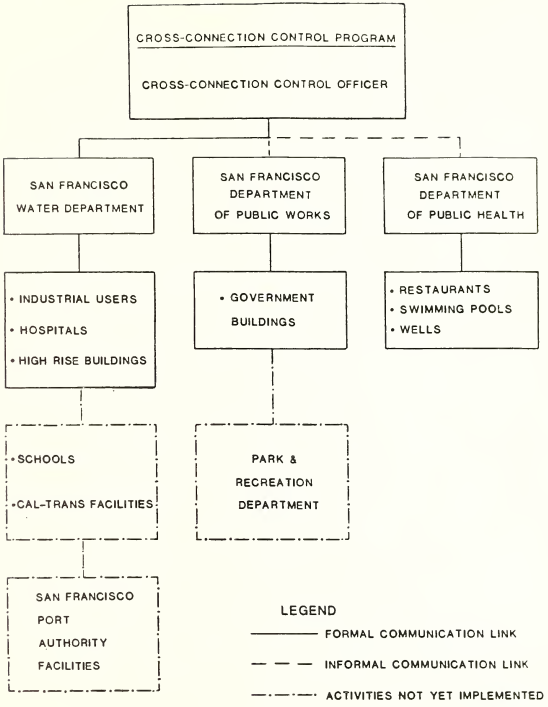

FIGURE 5-1.
CROSS-CONNECTION CONTROL
PROGRAM ORGANIZATION

The Department of Public Works is responsible for checking cross-connections on all public buildings. It is also evaluating the possibility of taking over the cross-connection control program at all Park and Recreation Department facilities. These would primarily be landscaping systems in City parks.

The Department of Public Health is responsible for cross-connections at restaurants and swimming pools.

Communications between the three branches of the program are maintained by the cross-connection officer. However, there is no formal linkage for transfer of information between these three entities.

An ordinance on cross-connection which establishes a water quality control committee in the City and County has been introduced to the Board of Supervisors. The ordinance places the Water Department in a lead role on the committee. With the adoption of the proposed ordinance, a formal line of communication can be established between the three departments, consequently improving the effectiveness of the program.

Procedures

The procedures being followed by the Water Department staff have been adopted primarily from the State of California Department of Public Health manual on cross-connection control.

To complete the industrial site inspections, a list of industrial facilities was obtained from the Department of Public Works, which monitors industrial waste discharges. Each industrial facility was given a Standard Industrial Code (SIC). From this list, the Water Department scheduled and made site inspections. Hospitals in the City were identified from various lists; to date, the majority of the hospitals in the City have been inspected. Door-to-door inspections are being conducted on high-rise buildings.

Once a cross-connection case is identified, a card is filled out with all pertinent information. A schedule of testing and future testing is also established. A letter is sent to the water user indicating that an inspection was made and the corrective action which must be taken on the part of the water user. A list of acceptable backflow prevention devices and a list of certified backflow prevention inspectors are included with the letter for reference.

Recordkeeping

An index card system on backflow prevention devices is being established. Presently, 433 devices have been added to the active inventory of backflow prevention devices. All correspondence regarding the cross-connection control program is kept on file.

Equipment

At this time, the Water Department has two pieces of equipment used in the cross-connection control program: (1) a Midwest Model 890 double check/valve test kit, and (2) a Midwest Model 830, reduced pressure test. The equipment is in excellent condition and is well maintained.

Recommendations

The City's cross-connection prevention program is a concentrated effort of three City departments. A cross-connection ordinance is being submtted to the City and County Board of Supervisors for adoption. This ordinance calls for the establishment of a cross-connection control committee consisting of representatives from the Public Health Department, Public Works Department, and the Water Department.

Presently, there is no formal communication channel being established among the three departments. This situation will be improved when the cross-connection prevention ordinance is adopted by the Board of Supervisors. We recommend an informal task force represented by all three departments be established in the interim to provide the necessary information exchange and to enhance the effectiveness of the program. With respect to the program that is being implemented at the Water Department, program coverage, procedures established, and staffing level are satisfactory to serve the purposes intended.

CORROSION CONTROL PROGRAM

Corrosion control for facilities of a large water agency such as the San Francisco Water Department consists of two elements: internal corrosion control and external corrosion control.

Internal corrosion control is the protection of the interior surfaces of water conveying structures, pump stations, and pipelines. The methods of internal corrosion control include chemical addition, lining systems, and material selection. Cathodic protection is also used in conjunction with coating systems to protect the interior of steel water storage tanks.

External corrosion control involves the protection of buried piping systems and structures, and the protection of above ground facilities. Protection for buried structures is provided by coatings and/or cathodic protection, depending on system requirements. Above ground facilities are normally protected with coating systems.

Internal Corrosion Control

The Water Department's main corrosion control effort is the lime plant operation at Rock River. Raw water pH is being adjusted with the addition of 55 pounds per million gallons of lime to a

range between 9 and 10. As discussed previously in Chapter 4 of this report, corrosion indexes are being analyzed throughout the water system, but are not being used to guide the determination of lime feedrate at Rock River. The asbestos count within the City distribution system appears to be higher than that from Hetch-Hetchy and the treatment plants, suggesting pickup from the distribution system. Also, heavy metal concentrations in the raw sewage from the City's residential area are relatively high when compared to other sources. This finding suggests that the water may be leaching the metals from the aged water distribution system. These findings warrant in-depth investigations in the conditions currently existing so that the vast investment in pipelines can be properly protected.

Depending on the amount of blending with waters from Alameda County and the Peninsula reservoirs, the corrosion indexes vary within the conveyance and distribution system with no identifiable pattern. This is primarily caused by the low buffering capacity of the Hetch Hetchy water. The low total dissolved solids and low alkalinity of this water not only create difficulty in pH measurements, it also presents difficulty in the stabilization process. The Water Department is planning to undertake a study to evaluate the water chemistry and the corrosion behavior of the water supply.

To establish a baseline of information on water chemistry and corrosivity, bare steel coupons were tested in running water at the Millbrae laboratory, Irvington Portal, San Andreas filtration plant, and the Sunol filtration plant. The results indicated an average loss of material measured at 10 to 13 mils per year and confirmed that water being delivered under the conditions tested was aggressive. These results also suggested that the Water Department's increased attention on internal corrosion is necessary.

In July 1982, the Water Department purchased corrosion monitoring devices that were installed at:

- Alameda West Portal
- Irvington Tunnel
- Pulgas Tunnel
- Baden valve lot
- Fulton and 35th Street

Monthly readings were taken at these locations, and water samples were collected and analyzed to correlate the corrosion indexes and water quality parameters.

The Water Quality Manager is responsible for the Rock River lime station and the Assistant Water Quality Manager is responsible for the on-going corrosion study. Two staff members from the Millbrae laboratory are involved on an as-needed basis to provide necessary staff support. The Water Department is adding an associate water quality engineer position to the Water Quality Division. When filled, this associate engineer will be assigned to undertake a more comprehensive study program, including the addition of more monitoring stations and the evalution of using other corrosion inhibitive chemicals such as zinc orthophosphate.

External Corrosion

Presently, there is no formal corrosion control program designed for the San Francisco water system. Corrosion control projects are identified and handled on an individual basis by the divisions directly affected. Over the years, work on corrosion control has included:

- A project report on electrolysis on San Joaquin pipelines Nos. 1 and 2 completed in January 1962.
- A report on corrosion on pipelines near the San Francisco International Airport, completed in October 1967.

- A report on Bay Division pipelines, Section B, completed in March 1971. The installation of a cathodic protection system for this section was completed in 1975.

- A report recommending cathodic protection for the San Joaquin pipelines near the San Joaquin River crossing. The installation was completed in 1983.

- A draft report completed in October 1983 on corrosion control for pipelines and related structures on the San Francisco Peninsula.

Most of these reports indicate that the pipelines and structures being investigated are in need of corrosion control mitigation measures. These reports point to aggressive soil conditions, system configuration, and materials used as key factors affecting corrosion.

Currently, approximately $100,000 per year is budgeted for external corrosion control studies. Projects are initiated by the division directly involved with the particular facility to be studied. A project manager from the Utilities Engineering Bureau (UEB) budgets for the project and programs for the completion of the work. Projects may be completed by in-house staff or outside consultants. Once the engineering work is completed, a bid package is prepared by the Contract Administration Group of the UEB. Bids are received and the construction activities are monitored by the Construction Engineering Group of the UEB.

RECOMMENDATIONS

Internal Corrosion

With the on-going corrosion monitoring program and the addition of one associate engineer to the staff, the City's internal corrosion control program can be implemented satisfactorily provided study results are used to improve the current practice. We also recommend increasing the monitoring stations

to ten locations and extending the monitoring period to 3 years. Also, we recommend the following inclusions in the future evaluations:

1. Evaluate the use of alternative corrosion inhibiting chemicals, their effectiveness, and water quality implications. A senior chemist should also be assigned to assist the analysis and evaluation. This evaluation should ba coordinated effort with the lime feed evaluation as recommended previously.

2. Evaluate the changes in lime feedrates as related to asbestos counts in the water system. Recognizing that corrosion is a long-term process, monthly samples should be taken at 7 to 10 locations and the trend of asbestos counts should be plotted.

3. Analyze heavy metal content at selected locations in the City's distribution system to obtain a general picture of metal pickup as a result of corrosion.

External Corrosion

Considering the size of the City's water system and the amount of investment affected, we recommend that a comprehensive corrosion control program be implemented. The program should consist of three elements:

- Evaluation
- Implementation of corrective action
- Maintenance of corrosion control facilities

Evaluation. In addition to the projects that are being completed, a complete evalution of all water system facilities is recommended to assess the total magnitude of the problem:

1. Existing conditions of the facilities and conditions of damage. Emphasis should be on the City's distribution system where minimum work has been performed.

2. Causes of corrosion problems.

3. Areas in which corrosion control improvements are needed.

4. Establishment of priorities, schedules, and budget for the improvement program.

Implementation. The improvement program should be budgeted in accordance with the schedule. Corrosion control systems should be designed, tested, and installed. Those pipelines found to be in corrosive environments and in need of protection should be given top priority. Suitable construction and piping material should be recommended for particular uses and locations.

Maintenance. Once the corrosion control systems are installed, calibrated, and operated, the system must be tested and maintained for optimum service. Test station readings should be taken on a yearly basis and the voltage and amperage readings on the rectifiers should be taken every 2 months.

Summary

A comprehensive corrosion control program is a costly undertaking and should be an on-going program to protect the City's investment and to prolong the life of the facilities. This is of particular importance because many parts of the City's system have exceeded their expected design lives. Any extension to the life of the facilities represents savings to the City. The cost impact can be recognized from the estimated replacement cost of City pipelines. For 1984, the replacement cost is estimated to be $375,718,000. The achievement of 1% improvement will translate to a $3,000,000 savings for 1 year.

Budget. It is estimated that a comprehensive evaluation program will require approximately 3 years. The cost of the first phase evaluation including the development of a comprehensive improvement program is about $300,000 to $400,000 total for 3 years. The improvement program should indicate the improvement

elements, annual budget requirements for the first 5 years, and also estimate the funding requirements and other necessary improvements in 5-year increments for a program span of 20 years.

The program should be updated every 5 years so that more updated cost figures can be developed and incorporated into the budgetory process.

Staffing. Presently, all corrosion control projects are being implemented through UEB. We recommend that the position of one full-time corrosion engineer at the level of associate engineer be created to coordinate and implement the corrosion control effort. This corrosion engineer position can be located in the UEB or in the Water Department, reporting to the Water Quality Manager or the Assistant Water Quality Manager, similar to the cross-connection control program. One part-time technician should be assigned to the corrosion engineer to routinely take readings and maintain the corrosion control facilties.

Chapter 6
OPERATION OF LABORATORY

The San Francisco Water Department's laboratory, located at the Millbrae complex, has the responsibility of providing analytical testing services required to monitor the quality of water and generate data for the preparation of necessary reports to the State Department of Health Services.

Four distinct sections of the laboratory provide testing capabilities in one of the following areas: bacteriological, wet chemical, instrumental, and limnological. In addition, capabilities exist and have been used to perform bench-scale research studies for improving water quality, such as the trihalomethane formation potential of alternative disinfectants, the chloramine study, and the corrosion study.

The laboratory staff consists of two senior water chemists, six water quality chemists, and three assistants. The technical and administrative responsibilities of these eleven people are delineated in Table 6-1.

The staffing level at the Millbrae laboratory is adequate to handle the routine load of analytical work. Education levels and experiences of the staff are satisfactory to perform the assigned duties in the four areas discussed above. One senior chemist is in charge of the wet chemistry and the bacteriological laboratory and the other senior chemist is responsible for the instrumentation laboratory, limnology studies, and special research projects.

The laboratory operates 7 days per week with one shift, and overtime on Mondays and Thursdays to accommodate the large number of bacteriological samples.

Table 6-1. LABORATORY STAFF AND RESPONSIBILITIES

Staff	Responsibilities
Senior chemist	1. Oversees and directs activities of microbiology and wet chemistry laboratories. 2. Trains subordinates. 3. Inspects WTP laboratories. 4. Conducts field testing and investigations.
Senior chemist	1. Oversees and directs activities of instrumental section of laboratory. 2. Oversees and directs watershed/reservoir limnological studies. 3. Performs and directs complex analyses and special studies. 4. Trains subordinates. 5. Conducts field investigations and research projects.
Water quality chemist	1. Performs analysis in instrumentation laboratory. 2. Performs special studies.
Water quality chemist	1. Collects special samples. 2. Makes bacteriological tests and reports. 3. Prepares media. 4. Investigates complaints.
Water quality chemist	1. Performs chemical, bacteriological, and corrosion analyses. 2. Performs analyses related to complaints and leaks.
Water quality chemist	1. Conducts plankton analyses, reservoir surveys, and limnological studies. 2. Conducts corrosion analyses. 3. Implements special projects.
Water quality chemist	1. Performs chemical and mineral analyses. 2. Conducts laboratory preparations.
Water quality chemist	1. Collects and analyzes pressure zones and tanks in the system. 2. Performs bacteriological analyses. 3. Monitors quality control.
Lab assistants (three)	1. Collects samples. 2. Performs field chemical analyses. 3. Assists in bacteriological analyses. 4. Prepares glassware and media.

SAMPLE LOCATIONS AND SCHEDULE

There are approximately 195 locations covering raw water sources, transmission lines, and distribution systems from which samples are collected at least once per week for various chemical and bacteriological analyses. The most frequent analyses performed on samples from these locations are coliforms, turbidity, alkalinity, hardness, chloride, conductivity, chlorine residual, temperature, pH, and fluoride. Each of these analyses and their respective schedules are discussed separately.

Coliforms

Samples for coliform analyses are collected from approximately 186 locations. The number of locations sampled and analyzed are broken down as follows by the sampling frequency.

Frequency	No. of locations	No. of samples/week
Daily	16	112
Twice per week	61	122
Once per week	109	109

The locations sampled daily include each of the Bay crossing lines, three points within San Francisco airport, Crystal Springs pipeline No. 2 at Millbrae, Sunset supply line at Millbrae, San Andreas pipeline No. 2 at Baden, Pulgas-North, Sunset supply line at Casey Quarry, Crystal Springs pipeline No. 2 at Casey Quarry, the lower Crystal Springs reservoir outlet, the San Andreas Reservoir outlet, and the San Andreas filter plant outlet.

According to Article 3 of the California Health and Safety Code and the California Administrative Code, Title 22, the San Francisco Water Department with approximately 135,000 service connections is required to sample 54 points per week within the distribution system for bacteriological analyses. Currently, there are about 343 points sampled per week, signifying an excessive number of bacteriological analyses.

This additional sampling is required for the transmission system terminal points for each community along the aqueduct. With the City of San Francisco's hilly terrain, monitoring of each fragmented pressure zone also requires a substantial amount of additional sampling. In addition to sampling the inlet and outlet of each terminal reservoir located in the City, sampling for bacteriological analyses also includes the inlet and outlet of all hydropneumatic systems. In addition to the large number of samples being processed, many coliform analyses are run in duplicate or quadruplicate.

Turbidity

Samples for turbidity analyses are collected from approximately 103 locations weekly including surface reservoirs, transmission lines, and points within distribution systems. Due to the number of distribution reservoirs within the system, the number of turbidity analyses appears to be adequate.

Alkalinity, Hardness, Chloride, Conductivity

Samples from approximately 56 locations are analyzed weekly for alkalinity, hardness, chloride, and conductivity. These analyses are performed at many locations in the transmission system, the storage reservoirs, and the City distribution reservoirs.

Chlorine Residual

Chlorine residual analyses are currently performed whenever samples for coliforms are collected from disinfected waters.

Temperature, pH, and Fluoride

Presently, the laboratory analyzes 101 locations for temperature and pH. Temperature measurements are made whenever fluoride samples are collected. Most of the temperature and pH analyses are performed whenever the alkalinity, hardness, and chloride tests are conducted.

Additional Schedules

Twice per year the surface supplies are subjected to complete mineral analyses, including analyses for the six pesticides identified in the Primary Drinking Water Regulations. These locations are as follows:

- Hetch Hetchy Reservoir
- Alameda East Portal
- Calaveras Reservoir
- San Antonio Reservoir
- Pilarcitos Reservoir
- Stone Dam Reservoir
- Lake Merced Reservoir
- Sunol filter galleries
- Pleasanton well field
- Cherry Reservoir

Results of the partial mineral analyses and bacteriological analyses on the distribution system are submitted to the State Department of Health weekly and monthly.

The laboratory also performs chemical and physical analyses on samples generated from consumer complaints and system leaks. The volume is approximately 10 to 20 samples per week, and the analyses are generally for one or more of the parameters described above.

Samples generated from possible cross connections are subjected to a more comprehensive series of tests including ammonia and uric acid.

SAMPLE ANALYSIS METHODS AND QUALITY CONTROL

The analytical methods employed were those accepted and approved by the USEPA, State Department of Health Services, and AWWA for the testing of potable waters. The fluoride analyses were performed by the colorimetric technique, but have recently been switched to the more efficient electrode method. Without the distillation process, the time required to perform the analyses is reduced.

The laboratory is currently using the multiple tube fermentation (MPN) procedure for coliform analyses, which is more time consuming than the membrane filter technique. The primary reason for not using the membrane filter technique is concern that data obtained from the City's unfiltered water would be difficult to interpret. The second reason was that the MPN method lends itself to be mass processed in a short period of time, if all the preparation work is done in advance. With the current sampling schedule and the amount of samples to be processed, the MPN method is satisfactory to produce the desired results.

The quality assurance and quality control program at the laboratory is informal. Some of the chemists have incorporated their own QA/QC procedures into their analytical tasks. Twice annually, the State Department of Health Services will send in samples for analysis to ensure that the laboratory analytical procedures meet state requirements.

RECORD AND REPORTING SYSTEM

The data management system existing at the laboratory relies entirely on manual data processing. Considering the volume of data generated by the laboratory, it is difficult to perform manually statistical or trend analyses on selected data sets.

Presently, the data compiled by the laboratory consists of analytical results and the associated sampling information that includes date, time, and onsite measurement. The analytical results that are generated daily are entered into bench sheets by the chemists. The daily results are in turn transposed onto weekly and monthly summary sheets. All data contained in daily, weekly, and monthly reports are stored in file drawers.

The routine analytical testing is supplemented by testing required for consumer complaints. The normal complaint procedure is that when a complaint is registered at the office in the main City yard, sampling of the water is performed the same day.

Requests for non-routine analytical services (such as complaints and leaks) are being handled by the senior chemists. Depending on the nature of the problem, one chemist will select the appropriate analytical procedures to ascertain the presence and magnitude of a water quality problem, and report the results to the Water Quality Manager or the Assistant Manager. Interpretation of data is not the responsibility of the laboratory staff.

ASSESSMENT AND RECOMMENDATIONS

The Millbrae water quality laboratory is charged with the responsibility of providing analytical support to the operation of the water system. The laboratory's primary duty is to perform routine analyses to satisfy the regular reporting needs to the State Department of Health Services.

The laboratory also conducts sampling and analyses of the raw water reservoirs and of water along the Hetch Hetchy and Suburban system to monitor the water quality changes. In addition, the laboratory analyzes water samples related to customer complaints. Capability is provided to conduct analyses for research and studies to improve the operation of the water system.

Because of the assigned duties, the Millbrae laboratory is being operated as a support group to the Water Quality Division as intended. The staffing level, performance, and staff training are satisfactory to serve in this supporting role. The majority of the work (>90%) can be classified as routine, offers little challenge, and requires little innovative and creative thinking.

In the case of most large water utilities, when the laboratory is staffed with the level of personnel such as San Francisco and is equipped with state-of-the-art instruments, laboratories are often charged with the duty of continuously investigating new ways to improve operation of the water system. This expanded responsibility puts the laboratory in the role of actively participating in the daily operation of the system instead of the supporting role, which is being assumed presently. Since the momentum of a water utility is often observed through the activities in the water laboratory, we recommend the City consider expanding the role of the laboratory to be a division equal to the Water Quality Division. This change will accomplish two purposes:

1. Provide the proper checks-and-balances of the water system operation on every day operation of the system, performing the primary function of quality control.

2. Provide support directly to the Hetch Hetchy, Suburban, and Water Quality divisions in evaluating current operational practices, conducting research projects, and recommending future improvements in an effort to better the services that are being delivered.

Recommendations made in this section are aimed at the accomplishment of these objectives.

Organization and Staffing

To assume more of a leading role in bettering the water system operation to meet future needs, we recommend the addition of a laboratory director to the current staff. He should be a chemistry major with administrative experience, familiar with water works practices, and preferably with a doctor's degree. His responsibilities will be:

- Administer the laboratory personnel
- Prepare annual budgets, equipment, and personnel requisitions
- Establish formal quality control/quality assurance program
- Determine sampling program locations, frequencies, and analyses to be performed
- Coordinate with other division managers and identify research subjects
- Direct study projects
- Interpret laboratory results
- Direct statistical and trend analyses
- Follow development of federal drinking water regulations and identify areas of need
- Perform staff training

Organizationally, one option will be to have the Water Laboratory be separated from the Water Quality Division. The Laboratory Director reports directly to the General Manager or the Assistant General Manager. Administrative and clerical support for this new division can be shared with the Water Quality Division until such time that the workload requires additions.

An alternative will be to have the water treatment superintendent in charge of all treatment facilities and operations, including Rock River, Tesla Portal, the two treatment plants, treatment facilities on the Peninsula, and the City chlorination stations.

The Water Treatment Superintendent and the Laboratory Director will be reporting to the Water Quality Manager independently to provide the checks-and-balance necessary in an organization for production and quality control.

This organization modification suggests four separate functions under the Water Quality Manager:

- Water treatment - production
- Laboratory - quality control and research
- Cross-connection prevention
- Corrosion control program

The Water Quality Manager will delegate responsibility of daily operations to the Water Treatment Superintendent; the Water Quality Manager will be responsible for:

- Administering and managing the Water Quality Division
- Coordinating water quality concerned issues with other division managers
- Performing water quality planning for the water system

Sample Locations and Schedules

To accommodate the additional workload generated from the new duties, it is necessary to reevaluate the existing sampling program. Our examination of the existing sampling frequency and analyses that are being performed suggests that the current sampling program be closely evaluated.

Coliforms. Of the 343 samples analyzed on a weekly basis, reductions can be made on some locations such as the reservoir inlets and hydropneumatic tank inlets. The necessity of performing quadruplicate California tests needs to be assessed.

Scheduling of the samples needs to be examined so that heavy loads of samples arriving on Mondays and Thursdays can be more evenly distributed to other weekdays. When samples can be analyzed on a more even schedule, the feasibility of using membrane-filter analysis should be evaluated. It is recognized that the MPN (multiple tube) method is a preferred method by the State Department of Health Services for its simplicity in data interpretation and lower skill level requirement for operators of small facilities. For larger size utilities, it would be more efficient to use the membrane filter technique. Large utilities using this method include Las Vegas, East Bay Municipal Utility District, Santa Clara Valley Water District, Los Angeles Water and Power, Boston, and New York. The last two cities are serving unfiltered water to their customers similar to San Francisco.

Alkalinity, Hardness, Chloride, Conductivity. Locations requiring these analyses are raw water, treated water, and treated water after blending with unfiltered water. The number of samples can be reduced from the current 56 locations to possibly less than half this number.

Chlorine Residual. Chlorine residual should be analyzed when samples for coliforms are collected. The number of analyses will be reduced when the coliform analyses are reduced.

Other Analyses. Complete mineral analyses are performed at ten locations, twice annually. From the sampling locations, it appears that treated water and treatment plant output are not being analyzed for complete minerals. We recommend the addition of five to seven sampling points to the existing schedule including two for the treatment plants and five for City

distribution reservoirs. It will also be desirable to include Moccasin Reservoir water quality, particularly the plankton counts and turbidity during summer months.

In evaluating the existing sampling practices, there are some inconsistencies with respect to sampling frequency; for instance, the San Andreas plant is sampled daily and the Sunol plant weekly. Some City distribution reservoirs are analyzed more than others. We recommend a formal sampling schedule be prepared with the following information:

- Location
- Frequency of sampling
- Type of analyses to be performed
- Remarks as related to special reasoning

Recordkeeping and Reporting System

As discussed earlier, the laboratory data processing relies totally on manual labor. Considering the amount of data generated and the number of reports prepared on a weekly and monthly basis, automation of this process will have several benefits:

1. Reduce time required for data processing and reduce potential human error in the data transferring process.
2. Facilitate statistical and trend analyses, and provide more comprehensive basis for data intepretation and possible early identification of water quality problems.

Automation can be accomplished by using a microcomputer similar to the IBM-PC. The cost for hardware is approximately $3,000. Software programs for laboratory data processing and reporting are available from several sources including Metcalf & Eddy.

Cost of setting up the system on the PC is less than 40 hours. If the Water Department chooses to be equipped with a mainframe or minicomputer such as Control Data Corporation's PDP 70 to facilitate data processing, inventory control, and preventive maintenance scheduling, terminals can be provided at each division office and treatment plant, and laboratory data can also be processed using a centralized computing facility.

In summary, with a closer look at the sampling needs of the water system, it is expected that the routine workload can be reduced. The laboratory staff will be able to take on more study projects, as recommended in previous sections of this report.

Chapter 7
ALTERNATIVES TO CHLORINATION

Traditionally, disinfection has been used in water treatment for the destruction of pathogenic organisms harmful to human health. Strong oxidizing agents are used for this purpose; chlorine is the most commonly used agent.

Because of its considerable oxidizing capacity, chlorine reacts with many other substances dissolved or suspended in water, resulting in the formation of compounds that may be harmful to humans. Compounds of greatest concern are in the THM family, a group of halogens that has been demonstrated to be carcinogenic to testing animals. Gaseous chlorine, a toxic gas, also presented itself as a potential safety hazard because of the possibility of gas leaks.

Therefore, concerns about the San Francisco Water Department's disinfection practice are in two areas:

1. The formation of THM and alternatives to chlorination to lower the THM levels in the distribution system.

2. The safety concern of chlorine gas handling at the City's chlorination stations and alternatives to the use of gaseous chlorine.

Chlorine is currently employed as the disinfecting agent for the San Francisco water supply. Hetch Hetchy supply is chlorinated at the Tesla Portal. Flows from the two Bay Area filtration plants are chlorinated before entering the transmission system. Supplementary chlorine stations are also situated at strategic locations in the City transmission and distribution systems. Additional chlorine is also applied at outlets of nine reservoirs located in the City.

All stations use compressed chlorine gas as a source of supply. Ton (2,000 lb) containers are used at the Tesla Portal and Casey Quarry chlorine stations. At most other locations, 100 or 150 pound cylinders are employed. Only one of the City reservoir stations uses hypochlorite solution instead of gaseous chlorine.

The THM formation potential, as discussed previously, is higher at the raw water reservoirs. Since THM is being formed through the transmission system and distribution system chlorination, potential for THM formation is lowest at the City distribution reservoirs.

The level of THM, however, increased after chlorination at Tesla Portal and the treatment plants and increases along the transmission routes. The levels are highest in the City distribution system after chlorination at the City's reservoirs. The average level, based on the quarterly report to the State Department of Health Services, reaches 75 ug/L, which is lower than the regulated limit of 100 ug/L. In light of the possible lowering of THM standards suggested by the EPA, alternative disinfection methods need to be evaluated to lower the THM levels.

CHLORINE DISINFECTION

While chlorine is a very active disinfecting agent, if added in insufficient amounts it can react with many substances contained in water so that its disinfection properties are reduced or eliminated. For this reason, "breakpoint" chlorination is practiced in water supply disinfection. Breakpoint chlorination is defined as the addition of chlorine in excess of that required to oxidize any ammonia in the water. Continued addition of chlorine after the breakpoint when all chemical reactions are completed will result in a free chlorine residual that in turn destroys the pathogenic organisms in water. Breakpoint chlorination is also effective in the reduction or bleaching of

color. The particular advantage in the use of chlorine is the fact that the presence of residual chlorine ensures an environment incompatible with the existence of pathogens.

Chlorine may be purchased as a compressed gas (Cl_2) or in solution as sodium hypochlorite (NaOCl). Where gaseous chlorine is the supply, a chlorinator is used to meter the feed of gas into a water stream forming a chlorine solution, and the chlorine solution is fed to the water. Chlorinators are relatively compact devices, taking little installation space. Chlorine can be delivered in 100, 150, or 2,000 pound cylinders. When large quantities of chlorine must be used, such as at the Tesla Portal, an evaporator must be used to gasify liquid chlorine for feed to the chlorinators.

Hypochlorite systems consist simply of a storage tank and a solution metering pump. Sodium hypochlorite is marketed at chlorine concentrations of from 3 to 15% solution. The more common strength used for bulk supply is 12.5% chlorine. Dilution water is usually added to the meter pump discharge to reduce the solution strength to 0.5 to 1.0% chlorine by weight. The hypochlorite system takes much more installation space than the gaseous chlorine system. It would take over seven times the volume to store 12.5% hypochlorite in an amount equivalent to that held in the compressed gas cylinders.

The principal disadvantages inherent with the use of chlorine with certain sources of supply are (1) the formation of THM, and (2) the formation of distinctive tastes and odors in the reaction of chlorine with synthetic organics such as phenols. Use of sodium hypochlorite has the additional disadvantage of increasing the sodium content of the product water; high sodium content in water may be harmful to individuals who need to be on a low sodium diet.

CHLORAMINES

Chloramine is a weaker disinfectant than chlorine. If present in sufficient quantities, chloramines can be effective. Chloramines are formed by the reaction of chlorine with ammonia that may be naturally present in a source water. To provide effective disinfection of the Hetch Hetchy water with chloramines, it would be necessary to add ammmonia with the chlorine to produce the amount of chloramine required.

Research has shown that chlorine will tend to react first with the ammonia and form chloramines which do not react with the natural organics to form THM compounds. Usually, the amount of ammonia required is half of that for chlorine to complete the reaction.

The equipment assembly required to produce chloramines is relatively simple. It would include the standard chlorinator producing chlorine solution from chlorine gas along with equipment identical in design to feed ammonia solutions. Ammonia may be purchased as compressed gas stored in cylinders or storage tanks. Capacity of the ammonia solution feeder would be about half that of the chlorinator.

Use of chloramines has the distinct advantage of greatly reducing the THM formation potential. It does, however, have other obvious and less obvious disadvantages. While the ammonia reacts with chlorine, arresting the breakpoint process, undesirable taste and odor producing chlororganic compounds may remain undisturbed. In addition, chloramines--being compounds of nitrogen--could have reduced impact on controlling or reducing the proliferation of algae and other biological activities in the reservoirs. There is little background experience available in the assessment of these potential impacts. If chloramine disinfection is being practiced, hospitals and medical facilties using kidney dialysis machines should be notified; and the owners of tropical fish should also be alerted.

CHLORINE DIOXIDE

Chlorine dioxide (ClO_2) is a highly effective oxidizing agent with strong deodorizing and bleaching properties. Chlorine dioxide has, in fact, had common water supply application where phenols may be present in the source water. It also has been used where iron and manganese must be precipitated before filtration or where control of algae is important, particularly those with taste and odor producing characteristics. The reaction of chlorine dioxide does not form THM.

Chlorine dioxide is formed by the reaction of either chlorine or hydrochloric acid with sodium chlorite. Both sodium chlorite and chlorine dioxide are explosive and must be handled with care. While the equipment required to generate chlorine dioxide is relatively simple, it is more complex than that used for chlorine or chloramine disinfection. In addition to the standard chlorinator metering chlorine gas to form chlorine solution, the assembly includes a metering pump for sodium chlorite and a packed tower for the reaction of the two basic materials. The most common design will produce chlorine dioxide solution with a concentration of about 1,500 mg/L.

OZONE

Ozone is an allotropic variety of oxygen with the formula O_3. It is a gas with excellent oxidation or disinfection properties. Ozone, an unstable gas, is formed by ionizing oxygen in a high voltage electric field. Industrially, ozone is made by passing a current of oxygen or air between two electrodes subjected to an alternating current difference.

Ozone is the purest available oxidizer that can be used for disinfection. It has all the oxidizing properties of the other chemical disinfectants discussed above with no known deleterious

side effects. It reduces the THM formation potential by converting the precursors to the form that is more easily removed by other water treatment processes. Reaction with critical organic or plant matter will not produce unpalatable tastes and odors. Ozone is, however, a fairly new disinfectant adopted for the water supply field. It has been selected for the New York and Los Angeles systems as part of the treatment process.

Ozone is costly to use as a disinfectant both in the capital improvements required and in the electric power needed for operation. The basic equipment includes generators using glass and metal tubes along with transformer and air handling appurtenances. Designs of different manufacturers vary, but installation and operating costs are uniformly high when compared to the alternative methods of disinfection.

The distinctive disadvantage of ozone is its unstable character. Ozonation of the water supply must take place in a pressure atmosphere compared to the open contact chambers used for the other alternatives. Oxidation is very rapid. Excess ozone is quickly released from the surface of the water on reduction of pressure. Ozone degenerates to O_2 in a relatively short period. It is also noted that ozone has an acrid odor, disturbing to nasal membranes if breathed in sufficient amounts. Because of these features, every drinking water ozone system must have the following:

1. An ozone destruct system (heat) to eliminate ozone excess to the process in treatment.

2. A chlorinator to add chlorine to produce a residual in the distribution system to ensure proper disinfection throughout the system.

After ozone oxidation, there are few, if any, reactants remaining to form THM with the addition of chlorine. The principal disadvantage of the ozone system is the cost, which can be especially high in a retrofit situation where the contact chamber

must be covered, pressurized, and fitted with an ozone release and destruct system. Also, little background knowledge exists about the reaction of ozone and the organic matter that may be found in water.

COMPARISON OF ALTERNATIVES

Without field tests, it would be difficult to make an exact comparison of the relative advantages of the use of the optional methods of disinfection for any water supply. The tests would be necessary to determine the consumption of the particular oxidant necessary to satisfy the disinfection and nondisinfection requirement. While precise comparisons would not be simple, the probable ranking of the four alternatives discussed above in regard to cost and oxidizing power is presented:

Ranking*	Oxidizing potential	Cost
1	Chlorine	Chlorine
2	Ozone	Cloramines
3	Chlorine dioxide	Chlorine dioxide
4	Chloramines	Ozone

*Ranking in order of preference.

If the use of chlorine alone were to be precluded because of the THM potential, chloramines would be the most cost-effective alternative. The Water Department is presently conducting a treatability study using chloramines. Bench scale tests support the conclusions that chloramines are less effective as a disinfectant if fed at Tesla Portal where the pH of water is in the range of 9 to 10. The feasibility of relocation of the disinfection station upstream from Rock River lime station needs to be assessed. The City is also required by the DOHS to conduct pilot programs of chloramine disinfection in selected areas to evaluate the effectiveness of the process on a larger scale before full implementation of the switch.

If the result of the chloramine study suggests negative impacts such as the taste and odor problems that are being experienced by the Alameda County Water District and Santa Clara Valley Water District, seasonal shutdown of the ammonia feed system may be necessary to accommodate the water quality changes.

Pending the outcome of the chloramine study, the City can proceed to study the cost effectiveness of the selection between chloramine and chlorine dioxide. Also, in any consideration of the chlorine dioxide process, the location and explosion potential must be included.

Although ozone is an effective disinfectant, it will be difficult to feed to the Hetch Hetchy system directly. A pressurized contact chamber would have to be installed, complete with excess chlorine destruction facilities to accomplish disinfection outside the pipeline. Chlorine facilities would also have to be retained to permit a chlorine residual in the pipelines. The ozone process will best be incorporated in the treatment processes for the proposed treatment plants, where staffing levels will be more adequate to manage this system.

FACILITY AND CHEMICAL COST ESTIMATES

The necessary additional facilities required to use either chloramines or chlorine dioxide for the Sunol and San Andreas filtration plants and for the Tesla Portal disinfection station are reviewed. Costs have been estimated for both the capital improvements and the annual cost of chemicals.

Chloramines

Two room additions are needed for ammonia storage and the installation of the ammoniator with appurtenant controls and piping. A storage tank would be installed in a well to prevent a quick flow or dispersal of ammonia should a major break occur.

Chlorination feed would remain as at present. Costs for the required equipment, the new building enclosure, and for electrical supply ventilation and other necessary appurtenances have been estimated as follows:

Location	Cost
Sunol filtration plant	$125,000
San Andreas filtration plant	125,000
Tesla Portal disinfection station	150,000
	$400,000

The facilities for the San Andreas plant were sized for anticipated expansion of that plant.

Chlorine Dioxide

The chlorine dioxide facilities would also have to be housed in a two-room enclosure similar to that for chlorine disinfection: one room for the sodium chlorite solution tank and one for the chlorine dioxide generation equipment. Olin Chemicals, principal supplier of sodium chlorite, will furnish the sodium chlorite metering pump and packaged column to contract customers free of charge. The existing chlorine solution line has to be rerouted to the mixing column. The chlorine dioxide solution line would be connected to the existing chlorine diffuser. Costs for the required new facilities and alterations have been estimated as follows:

Location	Cost
Sunol filtration plant	$100,000
San Andreas filtration plant	100,000
Tesla Portal disinfection station	115,000
	$315,000

Annual Chemical Costs

Annual costs for chemicals for chlorination compared to the chloramine and chlorine dioxide alternatives have been estimated:

Location	Chlorine*	Chloramine	Chlorine dioxide
Sunol filtration plant	$ 50,000	$ 80,000	$ 300,000
San Andreas filtration plant	20,000	32,000	122,000
Tesla Portal disinfection station	102,000	163,000	614,000
	$172,000	$275,000	$1,035,000

*1982 estimates.

It is obvious that the cost of adding the necessary capital improvements would be somewhat insignificant compared to the cost of chemicals.

ASSESSMENT AND RECOMMENDATIONS

Tesla Portal and Treatment Plants

To reduce the THM level in the City's system, we recommend the City continue the current chloramine study program and proceed to conduct the pilot scale testing as planned. If the results are favorable, we recommend an engineering feasibility study be conducted to evaluate the cost effectiveness of converting the Tesla Portal facility to chloramines as compared to relocating the disinfection station to a feasible site above Rock River, possibly Moccasin. The cost of a new station will be in the range of $400,000 to $500,000.

If the conversion to chloramine proves feasible and is installed at Tesla Portal and the two treatment plants, the City should conduct a testing program to evaluate the behavior of chloramine residual throughout the system. If maintaining the residual along the Peninsula becomes a problem because of the long travel time or taste and odor problem, the City should consider the

conversion of Casey Quarry to chloramine feed. This conversion would cost approximately $400,000. With a second feed point, the residual level in the City may be maintained and the use of the City chlorination stations eliminated.

In case chloramine disinfection is demonstrated to be unacceptable, bench scale and pilot scale testing should be performed on the use of chlorine dioxide. Realizing the difference in operating cost, the City's effort should be emphasized on developing the chloramine alternative.

City Chlorination Stations

When considering the safety issue related to the City's chlorination practice, the only practical alternative is the use of sodium hypochlorite. Some of the City stations do not lend to conversion without relocation. The cost of conversion is estimated to average $30,000 for a small station and $60,000 for each of the two large stations. Other concerns with respect to the conversion include:

- Increased truck traffic to the stations for solution transportation. Tank cars will be used instead of pickup trucks for chlorine delivery.
- Increased sodium level in drinking water may be a health concern for individuals with hypertension.
- The storage requirement for sodium hypochlorite at some stations may be large and require plastic lined or fiberglass tanks. The safety of these tanks to resist earthquakes is a primary concern. It was documented that tanks moved 4 feet during the Alaska earthquake. When tanks rupture under earthquake conditions, a containment may or may not prevent spills down the steep hills.
- Cost of sodium hypochlorite is higher than that of chlorine. Diluted solution at 12.5% has a short shelf life. Effectiveness of chlorination will diminish with time.

Recognizing the safety precautions that are being exercised at the City chlorine stations, we have concluded that the best alternative will be to retain the current practice. The risk for current practice is very low; chlorine accidents seldom occur and usually are caused during handling. Increased storage at each station will decrease the frequency of chlorine handling and also reduce the number of delivery trips through the neighborhood. Chlorine containers are steel of pressure vessel construction. Ratings are considered safe.

If the chloramine disinfection study proves feasible and supports the effectiveness of maintaining chlorine residual throughout the system, the City's chlorine facilties may not need to be operated in the future and this safety concern will be eliminated.

Appendix A
DETAILED TASK DELINEATION

Task 1. PROJECT INITIATION/DATA BASE DETERMINATION

1.1 Obtain Basic Data from City

1.1.1 Water quality analyses

1.1.1.1 Raw water services
1.1.1.2 Terminal reservoir outlets
1.1.1.3 Filter plant effluent
1.1.1.4 Distribution system (random locations)

1.1.2 Water Department organization structure by sections

1.1.2.1 Manager and supervisors
1.1.2.2 General staff

1.2 Develop Survey and Evaluation Forms

1.2.1 Facilities inspection

1.2.2 Staff interviews

1.3 Develop Survey and Evaluation Schedule

1.3.1 Inspection location

1.3.2 Staff interviews (by person)

1.4 Progress Meeting with City

1.4.1 Discuss additional background data needs

1.4.2 Discuss survey and interview procedures

Task 2 BASELINE INFORMATION AND APPARENT NEEDS DEVELOPMENT

2.1 General System Performance Review

2.1.1 Water quality records

2.1.1.1 Regulatory requirements
2.1.1.2 Aesthetics (secondary)

2.1.2 History of emergency or problem situation

2.2 Define Existing Water Department Organizational Structure by Section

2.2.1 Positions and responsibilities

2.2.2 Numbers

2.2.3 Education and experience

2.3 Define Existing Management Systems and Procedures

2.3.1 Watershed areas

2.3.1.1 Security
2.3.1.2 Permitted Access
2.3.1.3 Permitted Activity
2.3.1.4 Public Roads

2.3.2 Terminal reservoirs

2.3.2.1 Security
2.3.2.2. Sanitation
2.3.2.3 Quality control

2.3.3 Transmission system

2.3.3.1 Flow control
2.3.3.2 Chemical treatment

2.3.4 Filtration plants

2.3.4.1 Operation
2.3.4.2 Records
2.3.4.3 Routine and emergency maintenance
2.3.4.4 Operator training and continuing education
2.3.4.5 Performance (water quality and mechanical)

2.3.5 Distribution system

2.3.5.1 Chlorine disinfection (bacteriological and THM potential)
2.3.5.2 Volatile compounds
2.3.5.3 Asbestos
2.3.5.4 Other constituents
2.3.5.5 Corrosion control
2.3.5.6 Cross-connection program

2.3.6 Laboratory services

2.3.6.1 Sample locations and schedule
2.3.6.2 Sample analyses (constituents and procedures)
2.3.6.3 Record and reporting system
2.3.6.4 Training and continuing education

2.3.7 Chlorination practice

2.3.7.1 Location of feed
2.3.7.2 Equipment (maintenance history)
2.3.7.3 Quality performance (bacteriological and THM potential)
2.3.7.4 Costs
2.3.7.5 Alternatives to disinfection with chlorine gas including impacts on costs and potential benefits.

2.3.8 Progress report - existing system

Task 3 COMPARISON WITH OTHER LARGE SYSTEMS

3.1 East Bay Municipal Utility District

3.2 Metropolitan District Commission of Boston

3.3 City of New York

3.4 Report - Comparison SFWD

3.5 Progress Meeting

Task 4 ADJUSTMENT AND IMPROVEMENT NEEDS

4.1 Facilities

4.2 Management Organization and Procedures

4.3 Staffing

4.3.1 Numbers (by category)

4.3.2 Background experience

4.3.3 Training and continuing education

4.4 Risk Potential

4.4.1 Loss of services

4.4.2 Water quality impairment

4.5 Report

4.6 Progress meeting

Task 5 RECOMMENDED IMPROVEMENTS

5.1 Priority of needs

5.1.1 Facilities

5.1.2 Staffing

5.1.3 Procedures

5.2 Alternatives

5.3 Cost Estimates

5.3.1 Capital Improvements

5.3.2 Annual Operation

5.3.2.1 Salaries
5.3.2.2 Chemicals and materials
5.3.2.3 Energy

5.4 Functional and Environmental Comparison of Alternatives

5.5 Recommended System Improvement

5.6 Implementation Schedule

5.7 Report

5.8 Progress Meeting

Task 6 FINAL REPORT

6.1 Existing System and Apparent Needs

6.2 System Adequacy

6.3 Comparison with Other Systems

6.4 Adjustment and Improvement Needs

6.5 Appendixes (Background Data)

6.6 Conclusions and Recommendations

6.7 Schedule of Improvements

6.8 City Review

6.9 Report Revision

6.10 Executive Summary

6.11 Final Printing

Appendix B

COMPARISON WITH OTHER LARGE WATER SYSTEMS

SAN FRANCISCO WATER DEPARTMENT.....3-2

CITY OF NEW YORK.....3-4

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Appendix B

COMPARISON WITH OTHER LARGE WATER SYSTEMS

To provide a fair basis for assessing the current practices of the San Francisco Water Department's water quality management program, three large water systems were reviewed. Two of these systems are owned and operated by cities: City of New York and City of Boston. The third is owned and operated by a public water utility, East Bay Municipal Utility District (EBMUD).

The New York and Boston systems are selected because of their similarities with the San Francisco system. All of these systems provide largely unfiltered water from upper watersheds to their metropolitan customers. The EBMUD system is selected because of its proximity to San Francisco. The delivery of the high quality raw water from Pardee Reservoir to its urban customers via local terminal reservoirs is similar to that of the Hetch-Hetchy system; however, EBMUD filters its total supply.

Since all of these systems, including the San Francisco system, produce drinking water that meets all current regulatory requirements, this evaluation emphasizes the differences of organizational structures and management procedures. The most important aspect will be the organizational capability to perform long-range planning to meet the increasing water demand and the changing regulatory environment.

This section presents a brief description of each of these water systems. Significant features of their operation are highlighted; areas of differences are also discussed. To provide the proper basis for comparison, San Francisco Water Department's organizational structure and operational features are presented initially.

SAN FRANCISCO WATER DEPARTMENT

To operate the vast system as presented previously, the San Francisco Water Department, with over 500 employees, is organized as shown in Figure B-1. Under the General Manager (the Executive Division), the organization is divided into four divisions: City Distribution, Suburban, Water Quality, and Commercial.

Unique aspects of the Water Department organization and management are:

- San Francisco Water Department has no direct control of the raw water watershed and the operation of the powerhouse in the upper watershed and Hetch-Hetchy system. Operation of the water system has to be coordinated with the Hetch-Hetchy Division, which is outside of the Water Department's jurisdiction.
- The Water Department, with the exception of the Executive Division and the Commercial Division, serves the function of operation and maintenance of the water system.
- Each division independently operates a section of the system based on the physical location. The Water Quality Division is also an operating division and deals with the water quality aspects of the entire system. All division managers report directly to the General Manager.
- The Water Master is the pivot point of the system operations. Because of system limitations, water quality is one of the factors influencing the selection of water source and the delivery of water, but not the determining factor.
- The Water Quality Division operates the water treatment facilities including the lime station, chlorination stations, and water treatment plants. This division is also responsible for the water quality laboratory, which is charged with monitoring and data interpretation duties.
- Future planning of any capital improvements is initiated from each division and actual planning work is done by the Utilities Engineering Bureau. Because of the organizational constraints, systemwide long-range planning cannot be accomplished within the Water Department.

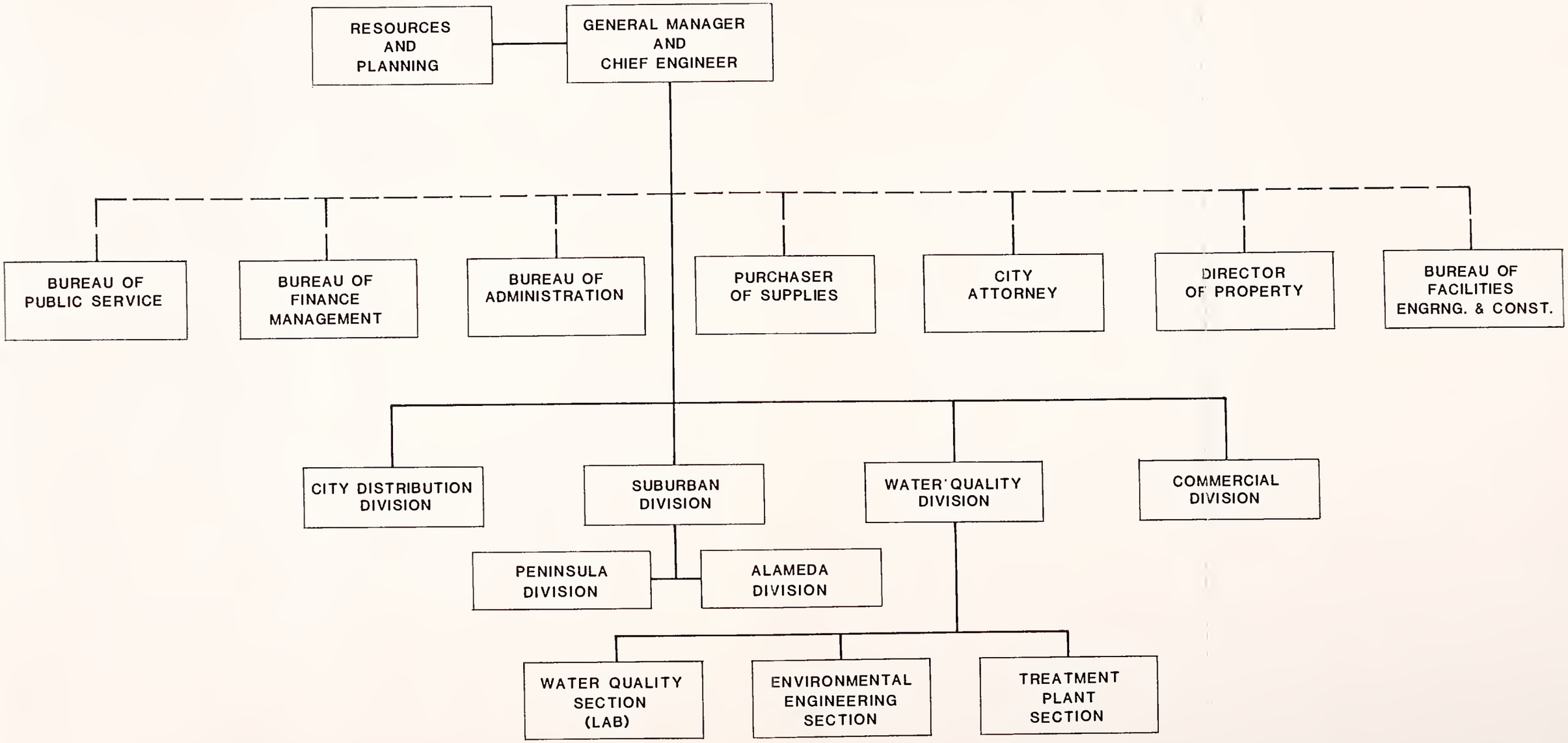

FIGURE B-1.
SAN FRANCISCO WATER DEPARTMENT
ORGANIZATION CHART

CITY OF NEW YORK

The Bureau of Water Supply (BWS) of the City of New York is responsible for collecting, impounding, treating, transmitting, and distributing the vast majority of the potable water supply to New York City. Only one area in the city is served by the Jamaica Water Company, an investor-owned utility. The BWS protects, operates, and maintains the watershed, reservoirs, pipelines, and other facilities in the city water supply system. The BWS also manages the planning, design, and construction of new waterworks.

The BWS's organization is presented in Figure B-2. Aspects of New York's system are:

- The City has total control of watershed management, owns and operates its entire system.
- The BWS is one of five bureaus in the Department of Environmental Planning (DEP) which has direct jurisdiction of wastewater management in all watershed areas and the city's service area. The DEP also provides laboratory services to both water and sewage bureaus.
- All divisions related to the operation and maintenance of the system report directly to the Director of Water Supply. The Deputy Director of Engineering is responsible for the planning and capital programs, and design and construction of systems.
- The operation of the system is separated from the maintenance function of the system. Water quality management responsibility lies with every division of the BWS.
- Laboratory support is obtained from the DEP. Monitoring programs and data interpretation are provided also by the Bureau of Science and Technology under the DEP.

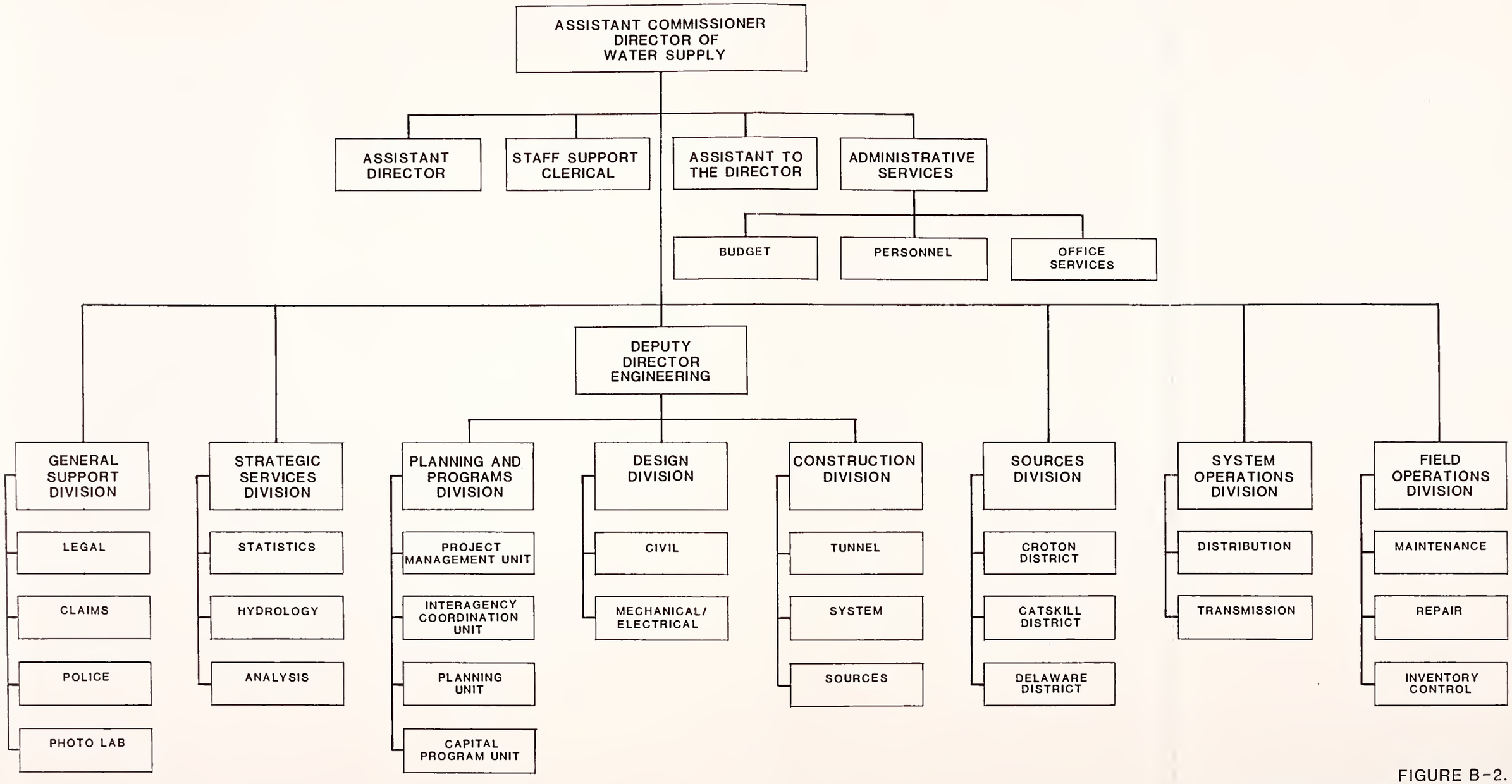

FIGURE B-2.
N.Y.C. BUREAU OF WATER SUPPLY
ORGANIZATION CHART

- Present water treatment includes chlorination for disinfection, fluoridation for therapeutic purposes, copper sulfate for reservoir algae control, and caustic soda addition for corrosion prevention. These procedures are largely similar to those being practiced in San Francisco. Water treatment is employed by either the Source Division or the System Operations Division. The city maintains a policy that all chlorination stations are manned around the clock.

- Because of the deterioration of the Croton Supply and the EPA regulations in promulgation, the BWS has started a program to add filtration to the Croton source. A pilot scale testing program has been completed; an ozone/diatomaceous earth filtration process has demonstrated to be most effective and economical. A 3-mgd demonstration plant is now being designed to facilitate the development of optimum design criteria. The ozone/diatomaceous earth filtration process offers flexibility: it can be mothballed during periods of high water quality.

- The BWS has no formal cross-connection control program. When deviations in water quality are found or reported, cross-connection investigation will be initiated to determine the source of the problem.

CITY OF BOSTON

The Boston Metropolitan District Commission's (MDC) water systems serve approximately 2.5 million people in 45 communities from Chicopee, Massachusetts, to Boston and has an average daily demand in excess of 300 mgd. The city owns approximately half of its watershed drainage araas and operates its entire water system on gravity.

The Water Division is one of four divisions of the MDC serving the greater Boston area. Other divisions include:

- Sewerage
- Parks
- Police

The Police Division serves all other divisions of the MDC; its principal role is to patrol and police all MDC owned properties. An organization chart of the Water Division is presented in Figure B-3. The division consists of four departments: Administration, Reservoir Operations, Metropolitan Operations, and Project Planning & Management.

- Boston MDC water system employs chlorination for disinfection, fluoridation for therapeutic purposes, caustic for corrosion prevention, and copper sulfate addition for algae control.

- Water treatment responsibilities lie with the respective operation department: either Reservoir Operations or Metropolitan Operations.

- The Sanitary Section of the Reservoir Operations Department provides control over the caustic and fluoridation station and also operates all of the laboratories. Its function is similar to the Water Quality Division of the San Francisco Water Department with the exception that the Sanitary Section of the MDC system reports to the Operations Manager.

- The supply sources and balancing reservoirs of the Boston system are ideally situated in a gravity flow pattern. No flow bottlenecks exist between the remote reservoirs and the balancing reservoirs. These reservoirs are essentially arranged in one string so that flow control is much simpler than that of the San Francisco system.

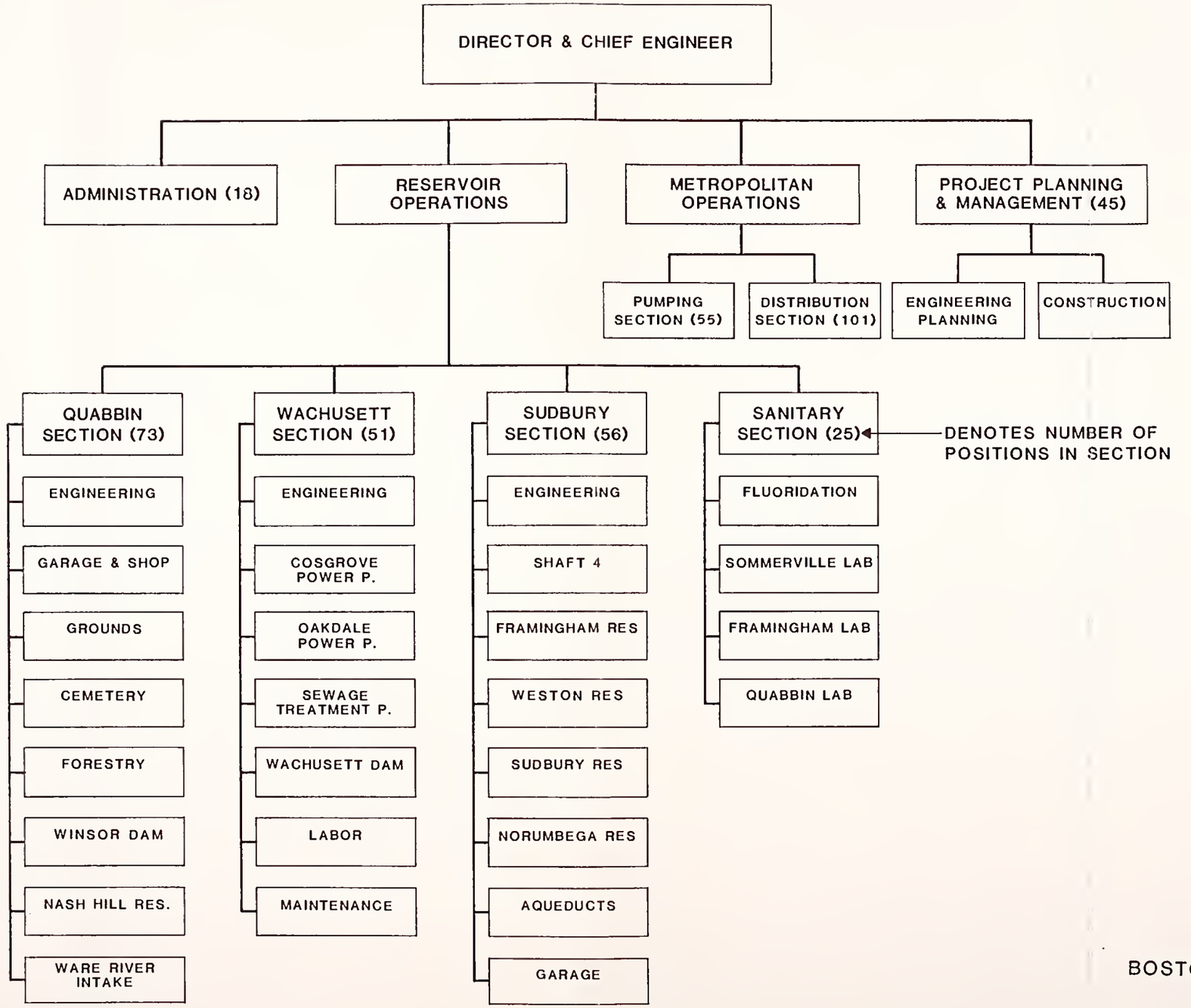

FIGURE B-3.
BOSTON MDC WATER DIVISION
ORGANIZATION CHART

- The MDC is presently investigating various methods for supplementing its available supply. The Sudbury source, which is not in use, is being evaluated as a feasible alternative. This source has the potential to have higher turbidity and trihalomethane (THM) levels: higher than that permitted under the established regulations.

  Treatment research has been completed for the Sudbury source and two filtration alternatives were selected: (1) a conventional filtration mode using a more cost-effective high-rate pulsator solids-contact unit for pretreatment; and (2) a deep bed activated carbon media filter preceded by ozonation. Ozonation reduces the THM potential and also serves as a microflocculant to minimize coagulant needs.

EAST BAY MUNICIPAL UTILITY DISTRICT

The East Bay Municipal Utility District (EBMUD) is responsible for the collection, transmission, treatment, and distribution of potable water to 30 communities in Alameda and Contra Costa counties. EBMUD currently serves approximately 325,000 water accounts representing one million users. The average daily water consumption in 1982 was 189 million gallons. The district also has the responsibility to treat the sewage collected from city-owned sewers within a nine community special district of approximately 600,000 people.

The majority of water for the system is imported from the watershed of the Mokelumne River in the Sierra Nevada Mountains near Jackson, California. The water is impounded in Pardee Reservoir and then transported approximately 90 miles to the terminal reservoirs in a three-barrel aqueduct. There are five

terminal reservoirs in the Oakland-Berkeley hills that balance the flow and impound some local runoff. All of the raw water from both the Mokelumne Aqueduct and the terminal reservoirs is treated at six water filtration plants before distribution to the customers.

Unique aspects of the EBMUD systems are:

- EBMUD is a public agency governed by a board of directors who works through the general manager and nine departments (Figure B-4). Five of the departments are nontechnical; these departments include Legal, Public Affairs, Personnel, Finance, and Administration. The remaining departments, Engineering, Water Operations, Maintenance, and Wastewater Operations, all have either direct or indirect responsibility for water quality.

- The Engineering Department is divided into two areas of focus: the design divisions and the planning divisions. The design divisions provide the engineering services necessary to design, construct, and operate all of EBMUD's facilities. The planning divisions are responsible for both short-term project planning and long-range goal planning. Both 5-year plans and capital improvement plans are developed to help guide the organization .

- The Engineering Department also serves as a support entity to the operation and maintenance departments to better the current practices. The Water Quality and Distribution Planning Section of the department is undertaking over 23 research projects not only to improve the system operation and maintenance but also to develop strategies to accommodate future regulatory changes.

- The Water Operations Department is responsible for all aspects of water quality. The Water Production Division is responsible for upper watershed powerhouse operation, raw water treatment, and patrol of Pardee watershed, aqueducts and rights-of-way. The Watershed/Recreation Division plans and manages watershed and recreation programs at the terminal reservoirs. Water quality related activities include vector control, collecting limnological data, erosion control, and fire prevention.

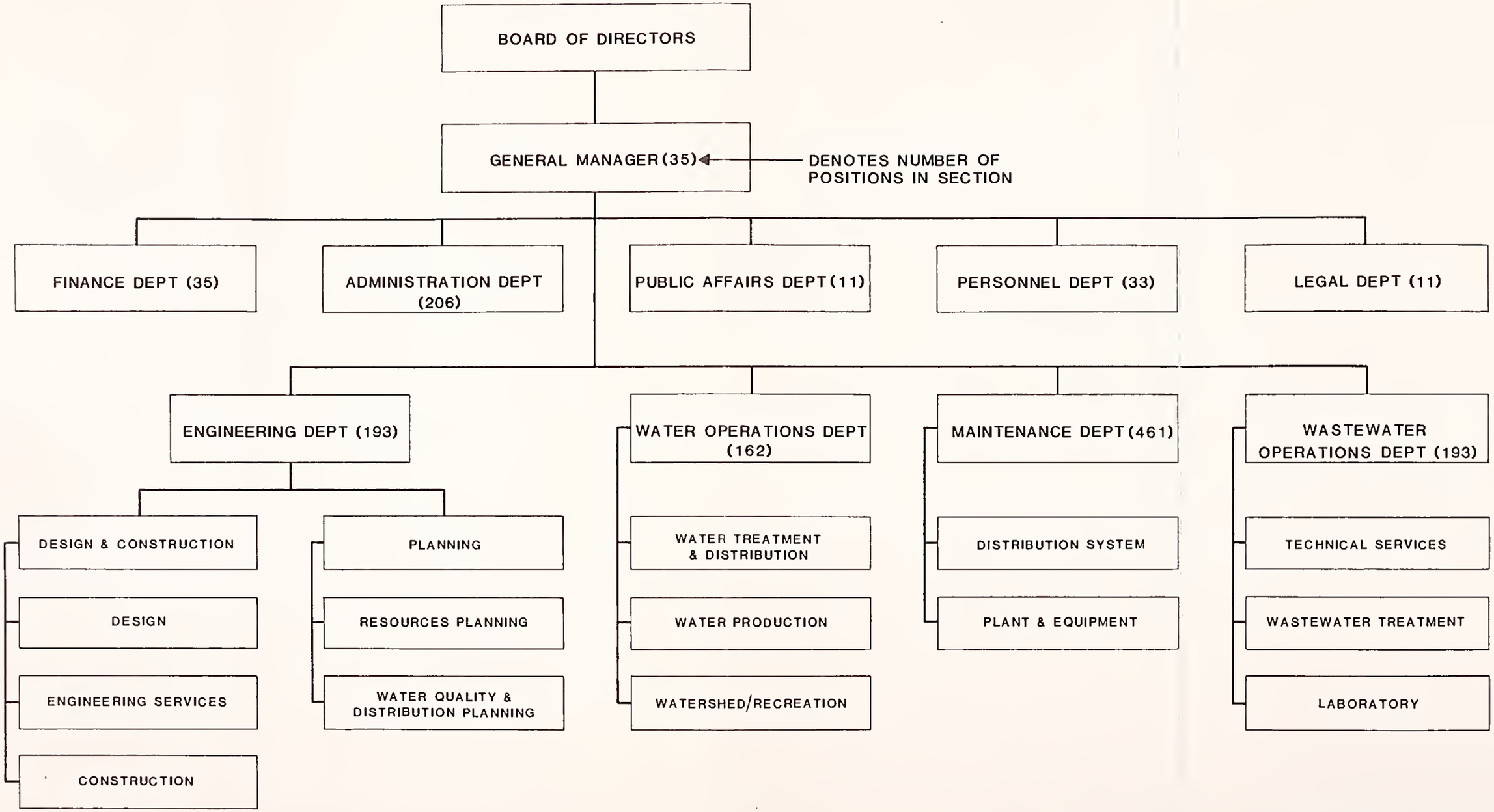

FIGURE B-4. EAST BAY MUNICIPAL UTILITY DISTRICT ORGANIZATION CHART

The Water Treatment and Distribution Division is divided into three sections: Water Quality, Water Treatment, and Water Distribution. The Water Quality Section directs raw water reservoir treatment and reviews and reports system water quality. It is responsible for the four-man cross-connection prevention program, investigating customer complaints, and water main and reservoir treatment. The Water Treatment Section is in charge of all water treatment operations and provides direction for water distribution system operation.

- The Maintenance Department provides scheduled preventive maintenance services to the Operations Department and corrective maintenance work on all repairs of the distribution system and the water treatment plants.

- Water treatment is provided for all of the water supplied to EBMUD's customers. The water is chlorinated at Pardee before entering the aqueduct, filtered in the Bay Area, rechlorinated, and fluoridated at the treatment plants. In addition, copper sulfate may be used in the reservoirs to control algae, and caustic soda is used to adjust the pH of the finished water.

  Currently the raw water at Pardee is chlorinated to obtain a 2 mg/L residual for quality control in the aqueduct. Facilities are under construction to change this practice so that an additional chlorination point is provided at an intermediate point on the aqueduct. Research has shown that the use of two injection points will lower the amount of THM formation and help EBMUD meet its goal of THM less than 25 micrograms per litre.

  All of the water supply, either from the aqueduct or from the terminal reservoirs, is filtered before entering the distribution system. The goal of the process is a water with a turbidity of less than 0.1 turbidity unit. Three of the filter plants have a direct filtration process for the raw Mokelumne water and three have a more conventional coagulation, sedimentation, and filtration process. Finished water is rechlorinated and fluoridated at the treatment plants. There are no chlorination stations on the distribution system. The six treatment plants are operated by a remarkably small crew consisting of six foreman and 34 operators.

- EBMUD receives most of its raw water from the Sierra watershed of the Mokelumne River, basically the same type of watershed as the Tuolumne watershed used by San Francisco. The system also uses terminal reservoirs for storage and local impoundments in a way similar to San

Francisco. However, EBMUD has decided to filter all of the raw water prior to distribution. Actual operation of the filtration plants requires less than 5% of the labor staff employed by EBMUD; maintenance is in addition to the 5%.

COMPARISON OF SYSTEMS

San Francisco and the three water systems discussed in this chapter are similar in many ways and all were originally developed on the premise that the best water for the metropolitan customers could be obtained by developing remote watersheds and conveying the naturally pure water to the city by gravity. All of the systems have over one million water users; all have been established for over 50 years; and all are part of a municipal utilities group.

Water Quality Management

The four systems all meet current, basic quality control parameters: water as sampled meets the EPA criteria. Management practices are different for each organization.

Watershed Security. San Francisco and New York both put tight limits on allowable activities at the reservoirs and on the watersheds. New York is the beneficiary of a state law that allows it to control all activities in the watershed that might impact water quality. EBMUD and Boston allow and even encourage recreational activities in the watersheds. All of the systems employ rangers, watershed keepers, or police to enforce sanitary regulations and maintain the watersheds. Again, San Francisco and New York put more emphasis on these programs.

Treatment. All of the systems employ chlorination of the main source water, additional chlorination at the distribution system, fluoridation, and copper sulfate addition to the reservoirs for algae control. New York and Boston do not have any filtration facilities but are both implementing filtration options for terminal reservoirs with inferior water. San Francisco provides full treatment for water diverted from the terminal reservoirs. However, unfiltered water from Hetch Hetchy represents 80% of the total production. EBMUD filters all of its raw water prior to distribution.

Organization

All of the four water departments evaluated are part of a larger utilities group. San Francisco is somewhat different since it is the only utilities group that does not have jurisdiction over wastewater management and is the only one to include a transportation unit. The main organizational differences between San Francisco and other water departments are:

1. San Francisco Water Department is the only one without a core group to perform critical engineering and planning functions

2. San Francisco Water Department is the only one that includes a separate Water Quality Division. The Water Quality Division operates independently and parallel to the other operations divisions, while all other water systems structure water quality management to be part of system operations.

3. Both New York and EBMUD organizationally provide separate maintenance divisions to perform all maintenance functions of the entire system. Boston has included in each of the operations divisions full maintenance capability. While San Francisco's City Distribution System and Suburban Division are fully staffed with maintenance personnel, the Water Quality Division depends on the Suburban Division for maintenance suport and is not self-sufficient.

4. The General Manager of San Francisco Water Department is directly responsible for operational divisions similar to the systems of New York and Boston. However, he is also directly responsible for the Commercial Division. This is similar to that of EBMUD's general manager who is not directly involved in operations.

5. The water quality control laboratory of the San Francisco Water Department is under the Water Quality Division. This is similar to Boston's organization. New York's and EBMUD's laboratories are not part of the water operations and maintain completely independent checks on quality control.

6. San Francisco Water Department is the only one that does not control the upper watershed and the operation of the facilities including transmission aqueducts and powerhouse. This segregation builds in operational difficulties and prevents total control of water quality.